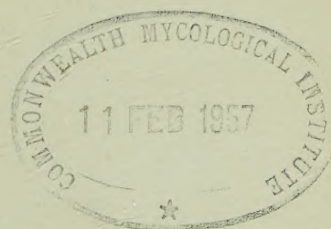


ANNUAL REPORT

of the

WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1955-56



ERRATA: 1954-55 REPORT

- p. 8, under P. B. Cornwell: *for* A.I.C.T.A. *read* D.T.A.
p. 33, Table 5: *for* lateritea *read* lateritia
—, —, —, —: *for* T. macrocarpa *read* T. microcarpa
p. 34, l. 21: *delete* often
p. 35, l. 38: *for* Side Nkawe *read* Sedi Nkawie
p. 36, l. 9: *insert* complete *before* results
p. 49, l. 16: *for* Leptmoastix *read* Leptomastix
p. 51, l. 38: *for* Trachsyphaera *read* Trachysphaera
p. 58, l. 2: *delete* D. J. Taylor and
p. 60, Table 13: footnote refers to last re-treatment, *not*
to shoot counts at 10 and 14 weeks
p. 73, l. 24: *for* seedlings *read* cuttings
p. 74, l. 37: *for* 23 *read* 2³
p. 81, l. 9: *for* below *read* in Table 22
p. 82, l. 32: *for* stating *read* tasting
p. 89, l. 4: *for* 60 *read* 30
p. 106, 4 (b): *for* squirting *read* spray-painting



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Her Majesty the Queen examining a demonstration of the Institute's work at Moor Plantation, Ibadan; *right*, the late Mr. J. Nicol (Officer-in-charge), Ibadan Sub-station; *left*, Dr. J. M. Waterston (member of the Managing Committee).

ANNUAL REPORT
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WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1955-56

Price 5/-

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MANAGING COMMITTEE

At 31st March 1956

CHAIRMAN

*Chief Secretary, West African Inter-Territorial Secretariat.

MEMBERS

*†Director, West African Cocoa Research Institute.

Chairman, Gold Coast Cocoa Marketing Board.

Mr B. E. Dwira, member of the Gold Coast Cocoa Marketing Board.

Mr J. H. Asafu-Adjaye, Gold Coast.

*Principal Assistant Secretary, Ministry of Agriculture, Gold Coast.

*†Director of Agriculture, Gold Coast.

Permanent Secretary, Ministry of Research and Information,
Federation of Nigeria.

†Director of Agricultural Research, Federation of Nigeria.

†Director of Agriculture, Western Region, Nigeria.

CO-OPTED MEMBERS (non-voting)

‡Director of Agriculture, Eastern Region, Nigeria.

†Deputy Director of Agriculture (Cocoa Industry), Gold Coast.

‡Principal Agricultural Officer, Southern Cameroons.

‡Secretary for West African Agricultural and Forestry Research.

Mr W. R. Feaver, Manager, Messrs Cadbury & Fry, Gold Coast.

Mr R. J. Smith, Manager, Messrs Rowntree-Fry-Cadbury, Nigeria.

Secretary, West African Cocoa Research Institute.

* Members of General Purposes Sub-committee.

† Members of Technical Sub-committee.

‡ Co-opted (non-voting) members of Technical Sub-committee.

SENIOR STAFF

At 31st March 1956

TAFO STATION

DIRECTOR	..	..	J. Lamb, O.B.E., M.SC., F.R.I.C., A.I.C.T.A.
ENTOMOLOGISTS	..	..	D. J. Taylor, B.SC., DIP. AGRIC. SCI., D.T.A. P. B. Cornwell, M.SC., A.R.C.S., D.I.C., D.T.A. *F. Raw, B.SC., PH.D. P. F. Entwistle, B.SC., A.R.C.S. Mrs Helen M. Entwistle, M.SC., A.R.C.S. (Temporary Entomologist).
PLANT PATHOLOGISTS	..	..	W. T. Dale, M.SC., A.I.C.T.A. A. L. Wharton, B.SC., DIP. AGRIC. SCI., D.T.A. G. Usher, B.SC., DIP. AGRIC. SCI., D.T.A. A. Attafuah (Assistant Specialist).
BOTANIST	..	..	A. D. McKelvie, B.SC., DIP. AGRIC. SCI., D.T.A.
CHEMIST	..	..	T. A. Rohan, B.SC., PH.D., F.R.I.C.
BIOCHEMIST	..	..	*Miss E. Margaret Holden, B.SC.
AGRONOMIST	.	..	R. J. Benstead, N.D.A., C.D.A.
SECRETARY	..	..	G. H. Neal.
ACTING SECRETARY	..	..	R. J. Webb.
GUIDE-DEMONSTRATOR	..	..	F. E. Decker.
STATION MANAGER	..	..	S. E. Ntim-Kwafo.

IBADAN SUB-STATION

OFFICER-IN-CHARGE	..	..	J. Nicol, B.SC.(FOR.)
PLANT PATHOLOGISTS	..	..	R. M. Lister, B.SC., DIP. AGRIC. SCI., D.T.A. J. M. Thresh, B.SC., A.R.C.S.
ENTOMOLOGIST	..	..	R. G. Donald, B.SC., A.I.C.T.A.

* Seconded from Rothamsted Experimental Station.

OBITUARY

MR & MRS JOHN NICOL

The news of the death of so many homeward-bound passengers in the air disaster at Kano on 24th June 1956 has greatly shocked people throughout West Africa. We at Tafo and Moor Plantation will miss, in particular, Mr and Mrs John Nicol of the Nigerian Sub-station.

John Nicol was born in 1911, and graduated from Aberdeen University. After working for some years with the Department of Scientific and Industrial Research in the United Kingdom on pests of stored products, he was appointed as an Entomologist to the Institute at Tafo in April 1944, the month of its inception. He was subsequently promoted to Senior Entomologist, and in December 1954 was posted to Moor Plantation as Officer-in-charge of the Sub-station.

He had a wide knowledge, not only of the entomological problems of cacao in West Africa, but of other aspects of its cultivation, and was always ready to give the benefit of his advice and experience when needed. His early work in West Africa was on the insecticidal control of capsids, and later he became associated with trials concerned with the possibilities of controlling the spread of cacao viruses by attacking their mealybug vectors with systemic insecticides. He was an accomplished photographer, as was recognised by his election to the Fellowship of the Royal Photographic Society. Many of his photographs of cacao and of its pests and diseases have been published in technical papers by himself and his colleagues. They will long remain a valuable contribution to the study of this crop.

As Officer-in-charge of the Sub-station, John Nicol was faced with many difficulties. His gifts for making friends and marshalling facts into convincing arguments enabled him to make considerable progress in establishing and equipping a new laboratory and staff accommodation. His untimely death is a severe blow to the progress of cacao research in Nigeria.

The Nicols had much to do with fostering social life, first at Tafo and later at Moor Plantation. As a founder member of the WACRI Club, 'Nick' helped enthusiastically in the construction of its amenities, including the tennis courts and golf course, the latter being part of a malaria-control project. His wife, 'Bessie', was an excellent hostess, and by her quiet friendliness did much to make newcomers to the Institute feel 'at home'.

All who knew them will sympathise sincerely with friends and relatives in their grievous loss. In particular, our sympathy goes out to their only child, Sheila, who is at school in Scotland, and to the aged mothers of Mr and Mrs Nicol.

ADMINISTRATION

MANAGING COMMITTEE

Meetings of the Managing Committee were held at Tafo on 6th-7th December 1955 and 15th March 1956. The Technical Sub-Committee met on 8th December and 13th March.

Mr F. R. Kankam-Boadu, Chairman of the Gold Coast Cocoa Marketing Board, has been nominated as one of the Board's two representatives on the Managing Committee, and will replace Mr E. A. Haizel at future meetings. Mr J. D. Broatch replaced Mr E. W. Leach, on succeeding him as Director of Agriculture, Gold Coast, and Mr A. W. Davies has taken the place of Mr J. Dixon as representative of the Gold Coast Ministry of Agriculture. Two nominees of the Federation of Nigeria, Hon. A. Obisesan and Mr E. A. Sanda, have resigned. Mr W. L. Cox replaced Mr C. J. Mabey as representative of the Federal Ministry of Research and Information, but was himself replaced by Mr D. J. Parkinson, who attended the second meeting.

Mr A. Pickles, formerly a member by virtue of his position as Acting Director of the Institute, has become a co-opted member of the Managing Committee and of the Technical Sub-committee, following his appointment as Secretary for West African Agricultural and Forestry Research. Messrs L. G. Heptinstall (West African Inter-Territorial Secretariat), A. F. W. Sheffield (Director of Agriculture, Eastern Nigeria), T. A. Phillips (acting for Mr Sheffield), D. Tallantire (Principal Agricultural Officer, Southern Cameroons), J. O. Torto and P. S. Hammond (each when acting as Deputy Director of Agriculture, Gold Coast) also attended meetings of the Managing Committee. Only Mr Heptinstall served at both of these, but the others each attended one meeting of the Technical Sub-committee.

FINANCE

As last year, the audit for 1955-56 had not been completed by August. It was therefore considered desirable to send this report to the printers, with the intention of publishing a supplement when the audited accounts become available.

The endowments from the Gold Coast and Nigerian Marketing Boards received in 1955 were invested, on the advice of the Crown Agents, in funds, bonds and various dated stocks in such proportions as to ensure availability at full value. It has, of course, been assumed that expenditure will be reasonably evenly distributed over the period

of endowment. The weakness of gilt-edged stocks in the early part of 1956 did not, therefore, give rise to any financial anxiety.

STAFF

Senior staff

Mr A. Pickles (Deputy Director) acted as Director until the arrival of Mr J. Lamb (Director), except for a seven-week period in April-May 1955, when Mr W. T. Dale (Senior Plant Pathologist) did so during Mr Pickles' absence on leave. Mr Lamb arrived and assumed duty on 1st November 1955, and Mr Pickles left the Institute on 16th November to take up his appointment as Secretary for West African Agricultural and Forestry Research.

Dr T. W. Tinsley (Plant Pathologist) and Mr H. R. Mapother (Insecticides Chemist) have returned to their substantive posts with Rothamsted Experimental Station and the Agricultural Research Council, respectively, on completion of their periods of secondment.

The resignations of Messrs J. F. Archibald (Horticulturist) and R. Knight (Plant Breeder) became effective during the period under review, though both had already proceeded on leave before April 1955. The former has joined the Uganda Department of Agriculture and the latter the Waite Agricultural Research Institute, Australia. These departures, followed by that of Mr H. H. Rogers (Plant Breeder) in May, to take up a post with the Cambridge Plant Breeding Institute, have meant that responsibility for all the work of the Botany Division has devolved on Mr A. D. McKelvie (Plant Physiologist) for virtually the entire period. As will be seen from later sections of this report, he has nevertheless contrived to maintain progress in various distinct lines of work. A Plant Breeder has now been recruited and is undergoing further training at the Plant Breeding Institute.

The resignation of Dr S. N. Adams, who has joined Rothamsted Experimental Station, threatened the continuity of important work on the nutrition of cacao. Arrangements have been made with Rothamsted for the temporary secondment of an officer experienced in this work, and a suitably qualified man is receiving further training there, with a view to permanent appointment. Mr R. Wickens (Agronomist) has also left the Institute for a post under the United Kingdom Ministry of Agriculture. His departure has reduced the strength of the Agronomy Division to one officer. It is proposed to increase the establishment of this Division but no success in this direction can yet be reported.

Mr P. B. Cornwell, who has been responsible for work on the bionomics and movement of mealybugs, and Mr R. M. Lister, Virologist at the Ibadan Sub-station, have also left to join the Atomic

Energy Research Establishment at Harwell and the Scottish Horticultural Research Institute, respectively.

This loss of well qualified senior scientific staff gives rise to serious concern for the Institute's future. The Managing Committee has decided to improve the conditions of service, with effect from 1st April 1956, in an attempt to stabilise the position. Vigorous attempts are being made to fill the numerous vacancies, which include certain proposed new posts at both Tafo and the Ibadan Sub-station. The task is a difficult one at present, due to the keen demand for scientific personnel, which is illustrated by the fact that all those leaving the Institute during the past year have gone to attractive posts. Fortunately, there is some indication that the position regarding agricultural scientists may soon improve.

The arrival of Dr T. A. Rohan in May 1955 has permitted a resumption of work on the chemical aspects of cocoa fermentation and storage. Mr P. F. Entwistle arrived at the beginning of September and is working on capsid problems. His wife, Mrs Helen M. Entwistle, also a qualified Entomologist, has been engaged on a temporary basis for investigations into the natural pollination of cacao, preparatory to assessment of the possible effect on it of insecticidal treatments. Mr A. Attafuah, a former Senior Technical Assistant in the Pathology Division, was promoted to Assistant Specialist in the same Division in April 1955.

On the administrative side there have also been changes, in addition to those involving the Directorship. Mr G. H. Neal proceeded on pre-retirement leave in March 1956 after ten years' service as Secretary of the Institute. We are grateful to the Crown Agents for Oversea Governments and Administrations for seconding Mr R. J. Webb as Acting Secretary, pending a permanent appointment. Mr F. E. Decker, formerly Senior Assistant Specialist in the Entomology Division, was appointed Guide-Demonstrator in January, but still finds a little time for entomological matters. Mr S. E. Ntim-Kwafo, Station Manager, has been in charge of the section formerly administered by the Maintenance Engineer, throughout the period under review. This follows the departure of Major C. Alderson, who went on pre-retirement leave in March 1955.

Junior staff

As was explained last year (*Ann. Rep. WACRI*, 1954-55, p. 12), members of the junior pensionable staff have been leaving the Institute for Government posts with better promotion prospects. To counteract this tendency, the Managing Committee granted a non-pensionable pay addition of 10 per cent. to these officers, with effect

from December 1955. One Technical Assistant from the Pathology Division has been seconded temporarily to the Nigerian Sub-station to assist with the virus work there.

Competition for appointments on the unestablished staff and for employment in the labour force is consistently keen, since wages and conditions of service compare favourably with those offered by Government. This is also true for the Sub-station, where the 'Gorsuch' rates have been adopted. Nevertheless, consideration is being given to means of improving the long-term prospects of those who are prepared to work hard and loyally in the Institute's service. Unfortunately, the present output level of many employees in the lower grades is far from impressive, and must be improved if the Institute is to do its best for the cocoa industries of the contributing countries. It must be realised that vociferous clamour is no substitute for hard and efficient work, which must be the sole criterion for advancement.

The mean daily attendance of unestablished staff and labour at Tafo and the Gold Coast out-stations was about 700, slightly higher than that for the previous year.

Health

The health record of the staff has been similar to that reported last year. There have been, as usual, a few cases of short-term fever, somewhat seasonal in occurrence and thought to be insect-transmitted.

We regret to record the deaths through accidents of two Technical Assistants, J. A. Armah (Management) and I. A. Antwi (Agronomy) and extend our sympathy to bereaved relatives and friends. The former died after being injured while playing football, the latter as the result of a motor-cycle accident.

The deaths of Mr J. Nicol (Officer-in-charge of the Ibadan Sub-station) and his wife, which occurred during the preparation of this report, are the subject of an Obituary on page 8.

PUBLICATIONS

The Proceedings of the West African International Cacao Research Conference, held at Tafo in December 1953, was issued in the latter half of 1955. It contains the introductory addresses, papers read or 'laid on the table', and full summaries of the lively discussions that developed. The following contributions were made by members of the Staff:

Archibald, J. F.: 'Factors concerned in the rooting response of cuttings', pp. 40-42.

Benstead, R. J.: 'Cacao re-establishment', pp. 95-98.

— 'Swollen-shoot Disease—WACRI', pp. 25-28.

- Cornwell, P. B.: 'Mealybug population, distribution and migration', pp. 8-17.
- Lister, R. M.: 'Notes on some case histories of Cacao Swollen-shoot Virus outbreaks in Nigeria as recorded by the Cocoa Survey', pp. 89-90.
- MacLean, J.A.R.: 'Some chemical aspects of Black-pod Disease in West African Amelonado', pp. 64-66.
- Nicol, J.: 'Chemical control of Cacao Capsids', pp. 49-51.
- 'The Capsid problem', pp. 51-52.
- 'The control of Mealybug vectors of Cacao Swollen-shoot Virus', pp. 18-20.
- Rogers, H. H. and Knight, R.: 'Some observations on yield trials of Cacao at Tafo', pp. 42-45.
- Taylor, D. J.: 'A review of the distribution of Capsid populations associated with Cacao', pp. 83-85.
- Tinsley, T. W.: 'The host range of the Cacao Swollen-shoot Virus complex', p. 22.
- 'The strains of Cacao Swollen-shoot Virus occurring in West Africa', pp. 20-21.
- Wickens, R.: 'Cocoa fermentation', pp. 67-68.
- A third Technical Bulletin, 'The propagation of Cacao by cuttings', by J. F. Archibald, was issued during the period under review, and the following papers giving accounts of work done at the Institute were published by past or present members of its Staff:
- Adams, S. N. and McKelvie, A.D.: 'Environmental requirements of Cocoa in the Gold Coast'. Rept. Cocoa Conference, London, 1955, pp. 22-27.
- Cornwell, P. B.: 'Some aspects of Mealybug behaviour in relation to the efficiency of measures for the control of virus diseases of Cacao in the Gold Coast'. *Bull. ent. Res.*, **47**, pp. 137-166, 1956.
- Knight, R. and Rogers, H. H.: 'Incompatibility in *Theobroma cacao*'. *Heredity*, **9**, pp. 69-77, 1955.
- 'Recent introductions to West Africa of *Theobroma cacao* and related species. I. A review of the first ten years'. *Emp. J. exp. Agric.*, **23**, pp. 113-125, 1955.
- Lister, R. M. and Thresh, J. M.: 'A mosaic disease of leguminous plants caused by a strain of Tobacco-mosaic Virus'. *Nature, Lond.*, **175**, pp. 1047-1048.
- Pickles, A.: 'The research policy and programme of the West African Cocoa Research Institute'. Rept. Cocoa Conference, London, 1955, pp. 117-121.
- Posnette, A. F. and Todd, J. M.: 'Virus diseases of Cacao in West Africa. IX. Strain variation and interference in Virus 1A'. *Ann. appl. Biol.*, **43**, pp. 433-453, 1955.

Rogers, H. H.: 'New varieties of Cacao in West Africa'. Rept. Cocoa Conference, London, 1955, pp. 76-79.

Various other papers have been prepared for publication, and several of these are already in the press. Mimeographed Quarterly Reports have been issued regularly during the year, and the Annual Report for 1954-55 was published during the latter half of 1955.

SCHOLARSHIPS AND TRAINING

As expected, the candidate for a WACRI post-graduate scholarship referred to in *Ann. Rep. WACRI*, 1954-55 (p. 15) could not be released from a bond to serve as a teacher, so no award could be made to her. Additional candidates, with qualifications from United States, United Kingdom, West African and Irish Universities or Colleges have been considered by the WACRI Scholarship Selection Board; but, up to the end of the period under review, it had not been possible to grant a scholarship. Some applicants studying at institutions in the United States seemed to view the proposed awards as potential sources of revenue to enable them to pursue studies of their own choosing, with little if any bearing on cacao research. The real idea is, of course, that a selected candidate should be trained as and where considered best by the Selection Board to fit him (or her) for the Institute's service.

Of the two members of the unestablished staff at Tafo selected for training with a view to appointment as Technical Assistants, one (Mr Bentum) is continuing his course; the other (Mr Yeboah) failed the first-year examinations and has returned to his former post at the Institute. Two candidates sponsored by the Sub-station completed the course of training for Agricultural Assistants at the Western Region (Nigeria) School of Agriculture, and joined the Ibadan staff in January 1956. Another employee, a Field Overseer, has been accepted into the School.

TOURING AND CONFERENCES

The London Cocoa Conference

Mr A. Pickles (then Acting Director) flew to England to attend the 1955 Cocoa Conference, held in London from 13th-15th September. Messrs J. Lamb (then Director-designate), W. T. Dale (Senior Plant Pathologist), D. J. Taylor (Entomologist) and R. Wickens (Agronomist), who were on leave at the time, also attended. We are grateful to the Cambridge Plant Breeding Institute and Rothamsted Experimental Station for permitting Mr H. H. Rogers and Dr T. W. Tinsley (former Plant Breeder and Plant Pathologist, respectively) to form part of our delegation. Papers presented by the Institute are listed on p. 13.

Swollen-shoot Symposium

A two-day symposium on cacao swollen-shoot viruses with special reference to Nigerian strains and conditions was held at Moor Plantation, Ibadan, during February 1956, under the chairmanship of Mr J. Nicol. In addition to the Sub-station's senior staff, Messrs Lamb, Dale, Benstead and Taylor of the Tafo Station attended. Officers of the Nigerian Federal Department of Agricultural Research and of the Department of Agriculture (Western Region) were also present. Following discussions led by Messrs R. M. Lister and J. M. Thresh of the Sub-station, and Mr J. Hadland of the Cocoa Survey Division of the Western Region Department, a full exchange of ideas took place. Treated outbreaks in the field were visited, and particular interest was shown in experiments on coppicing as an adjunct to cutting-out for virus control. This measure should lead to more economical control within the treated areas.

The venture proved most successful, and those present agreed that symposia on other subjects related to cacao would serve an equally useful purpose. It was felt that if such meetings were arranged, representatives of other interested Governments or organisations should be invited to attend, and that locations should be varied.

Leave visits and study leave

The Director visited various research institutions and chocolate factories before his arrival at Tafo, and most of those members of the senior staff on long leave in the United Kingdom paid similar visits for discussions with workers in appropriate fields. Messrs Taylor and Thresh were each granted several weeks' study leave. The former's was spent at Rothamsted Experimental Station, working on insecticide problems. The latter also spent the greater part of his time at Rothamsted, working with plant viruses, but also visited East Malling Research Station besides attending the International Horticultural Conference and the European Tree Virus Symposium in Holland. During February-March 1956, Mr A. D. McKelvie attended a four-week course at Harwell on the experimental uses of radio-isotopes. He also took the opportunity of visiting other research centres.

Other visits

After attending the meeting of the West African Inter-territorial Council, held at Bathurst in January 1956, the Chairman of the Managing Committee and the Director flew on to London for discussions at the Colonial Office on measures to stabilise the senior staff position.

Mr Pickles visited the Ibadan Sub-station in August 1955 and Mr Lamb paid his first visit to it in December. Mr H. R. Mapother

went there in May and Dr S. N. Adams in September, the former to advise on methods and machines suitable for insect control under Nigerian conditions, the latter to examine and give advice on the deficiency symptoms which sometimes appear on coppiced cacao. Mr McKelvie went to Western Nigeria in January 1956, to select sites for two new variety trials. After the symposium in February, Messrs Dale and Taylor visited cacao projects and experiments in the Western Region, while Mr R. J. Benstead made a trip to the Northern Region to assess the potentialities for cacao in Kabba and Ilorin Provinces.

Mr R. G. Donald of the Sub-station staff visited Tafo for discussions in November 1955, while Messrs Nicol and Lister did so the following January.

VISITORS

The Ibadan Sub-station participated in the arrangements made for the visit of Her Majesty the Queen and His Royal Highness the Duke of Edinburgh to Moor Plantation in February 1956. A demonstration of some aspects of the Institute's work was arranged, in which the Royal Visitors showed keen interest. His Excellency the Acting Governor of the Gold Coast, accompanied by the Regional Officer, Eastern Region, visited Tafo in May 1955. The Minister of Research and Information, Federation of Nigeria, has visited the Sub-station.

Visitors from the Colonial Office included Mr G. W. Nye (Deputy Agricultural Adviser to the Secretary of State) and Mr C. G. Eastwood. Five members of the Commonwealth Parliamentary Delegation and a Member of Parliament from the Union of South Africa have visited Tafo. Numerous visits to both stations continue to be paid by senior officers of the Gold Coast and Nigerian Departments of Agriculture and other British West African Government Departments. We are grateful to the Town Planning Division, Gold Coast Ministry of Local Government, for permitting Miss H. M. Richards to come to Tafo and submit suggestions on housing and layout of the residential area. Members of the Gold Coast Cocoa Marketing Board and its Nigerian (Western Region) counterpart have visited Tafo on several occasions during the year. We have also welcomed Dr F. B. Sands, Director of Agriculture, Liberia, and Messrs H. Helfritz and R. Vogler of the German Institute of Foreign Relations.

Besides maintaining close contact with workers at the University Colleges of the Gold Coast and Ibadan, we have welcomed an increasing number of overseas scientists. Dr R. L. Fowler, an American cacao expert with the U.S. Foreign Operations Administration, now working in Brazil, visited both Stations in May 1955. Another

American scientist, Dr F. P. Mehrlich, who was making a survey of problems associated with cocoa production in the Gold Coast, visited Tafo. Mr T. N. Hoblyn, Deputy Director of East Malling Research Station, arrived in March 1956 for a stay of several weeks, to advise on existing and proposed field experiments. Other visiting scientists have included Dr H. L. Penman, Head of the Physics Department, Rothamsted Experimental Station, and scientific representatives of various commercial interests. Amongst the latter, Dr G. R. Howat, Dr P. B. Powell and Mr G. A. R. Wood of Messrs Cadbury Bros., Ltd, spent some weeks at Tafo towards the end of 1955, carrying out interesting experiments on cocoa fermentation.

Mr C. Hatherley of Messrs Raw Products, Ltd, spent about ten weeks at Tafo early in 1956, familiarising himself with the work in progress. Other representatives of the cocoa trade who have visited the Institute include Mr P. Cadbury (Messrs Cadbury Bros.), Mr R. W. Leonard (Messrs J. S. Fry, Ltd), and three members from the International Office of Cocoa and Chocolate.

A number of representatives of firms concerned with the manufacture of insecticides, fungicides, and spraying equipment have visited both the Institute and the Sub-station. These include Messrs J. H. Stapley and C. M. Carr of Messrs Plant Protection, Ltd, Mr A. V. Coombs of the British Sulphate of Copper Association, Ltd, and Dr E. Evans of Messrs Fisons' Pest Control, Ltd.

Other visitors have included Miss Dorothy Hope-Smith, a freelance journalist-photographer. She took a number of photographs depicting life and work at the Institute, some of which have been used in a publicity booklet, designed to assist recruitment. We are grateful to Messrs Cadbury Bros. for the preparation of this booklet.

MANAGEMENT AND MAINTENANCE

Construction and maintenance of buildings

Most of the major works carried out during the period have been at Ibadan. The new laboratory block, a two-storey building containing thirteen rooms and laboratories was started in August 1955 and the outer fabric has been substantially completed. Furniture and benches are in process of installation. The block is most impressive and makes an excellent addition to the buildings of Moor Plantation. Ten insectaries were built at the Sub-station from imported metal frames on locally constructed concrete-block bases. A pipe-borne water supply has been laid to each and to the 'transmitting room', a small building constructed nearby.

At Tafo, the WACRI Club House has been greatly improved and extended at the Institute's expense.

Improvements have been made to several of the houses at both Tafo and Ibadan, and routine maintenance has been carried out on all roads and buildings.

Transport

All motor vehicles were kept in good working condition. A Chevrolet pick-up and a Land Rover have been purchased, the latter being allocated to the Entomology Division for use in its intensified spraying programme.

Water supplies

No difficulty was encountered in the running of the waterworks, and samples of water sent weekly for examination were all found free from pollution of any kind. Despite the long spell of dry weather in the early months of 1956 the stream feeding the reservoir did not cease to flow. It has been agreed that a water supply for the Tafo area should be provided from the reservoir. A separate plant for this purpose will, however, be set up by the Gold Coast Department of Rural Water Development. This should reduce the demands on the Institute's purified water, a great deal of which is taken away from our stand-pipes by villagers, particularly during dry spells. The mean daily production of potable water varied between 18,316 gallons in October 1955 and 28,507 gallons in February 1956, and consumption between 16,516 gallons in October and 25,145 gallons in January. The rainfall recorded at the waterworks varied from 15.51 in. in October to 0.67 in. in January, the total for the period under review being 63.20 in. contributed by 152 wet days.

Production of vegetables and meat

Totals of 4,714 lb. of green vegetables, 7,247 lb. of Chinese yams, 11,700 dry cobs of maize and 1,340 lb. of rice were produced for staff use. Mutton to the value of £29 14s. 0d. was sold.

COCOA PRODUCTION

TAFO STATION

The total amount of cocoa sold was 57,373 lb., which represents a decrease of 8,995 lb. (13.6 per cent.) compared with the previous year. This decrease is attributable in part to producing areas being taken over for experimental purposes and more pods being supplied for planting, but it is difficult to reconcile with the increased yield obtained from individually recorded plots of the Old Station, details for which are summarised in Table 1. These plots gave 15.9 per cent. more than in 1954-55, though 39.1 per cent. below the eighteen-year mean (see Table 2).

TABLE I

Yield of recorded plots, Old Station*

Date of picking	Total pods Harvested	Discarded	% Pods discarded	Pods fermented	Wet wt. of beans (lb.)	Dry wt. of beans (lb.)	% Dry to wet weight	Pods per lb. dry cocoa	Pods issued for expts.
1955									
June 6-13 ..	6,468	428	6.6	6,040	1,369.0	539.73	39.43	11.2	—
" 20-27 ..	5,757	257	4.5	5,500	1,331.9	536.20	40.26	10.3	—
July 4-11 ..	3,395	185	5.4	3,210	796.9	322.07	40.42	10.0	—
" 12-18 ..	1,241	65	5.2	1,176	326.7	130.73	40.02	9.0	—
" 25-27 ..	1,405	59	4.2	1,346	378.3	153.34	41.86	8.5	—
Total Minor Crop	18,266	994	5.4	17,272	4,202.8	1,687.07	40.14	10.2	—
Aug. 29-Sept. 7 ..	23,563	2,451	10.4	21,112	5,278.4	2,191.04	41.51	9.6	—
Sept. 12-20 ..	45,728	2,472	5.4	43,256	10,836.8	4,624.06	42.67	9.4	—
" 26-Oct. 5 ..	49,342	3,600	7.3	45,742	10,831.8	4,516.92	41.70	10.1	—
Oct. 11-25 ..	65,964	5,839	8.9	56,859	13,115.3	5,487.42	41.84	10.4	3,266
Nov. 1-16 ..	53,897	3,716	6.9	49,653	10,325.9	4,185.02	40.53	11.9	528
" 21-Dec. 6 ..	28,923	1,712	5.9	25,211	4,973.4	2,090.71	42.04	12.1	2,000
Dec. 12-21 ..	15,642	859	5.5	14,783	3,004.7	1,297.88	43.19	11.4	—
1956									
Jan. 3-10 ..	11,537	1,174	10.2	10,363	2,064.1	876.42	42.46	11.8	—
" 17-25 ..	7,087	1,268	17.9	5,819	1,055.3	425.77	40.35	13.7	—
Feb. 1-13 ..	3,765	1,011	26.9	2,754	478.5	209.32	43.75	13.2	—
Total Main Crop	305,448	24,102	7.9	275,552	61,964.2	25,904.56	41.81	10.6	5,794
1955-56 ..	323,714	25,096	7.8	292,824	66,167.0	27,591.63	41.70	10.6	5,794
1954-55 ..	293,811	26,249	8.9	261,930	56,460.6	23,588.19	41.78	11.2	5,632

* 63.69 acres of Amelonado cacao.

TABLE 2

*Comparative yield data from recorded plots, Old Station**

Season		Pods harvested	Percentage pods discarded	Total wet weight of beans (lb.)	% Dry to wet weight	Pods per lb. dry cocoa	Yield per acre
1955-56	..	323,714	7.8	67,326	41.7	10.6	440.8
1954-55	..	293,811	8.9	56,461	41.8	11.2	378.3
18-year mean		519,858	11.4	95,914	41.3	11.4	616.3

*63.69 acres of Amelonado cacao.

Picking in the recorded areas was carried out more frequently than during the previous season. The incidence of black-pod disease, as indicated by the number of unfermentable pods, was lower by 1.1 per cent. and the number of pods required to produce 1 lb. of dry cocoa fell from 11.2 to 10.6, these factors contributing to the increased yield. Contrary to early indications the crop ripened relatively uniformly throughout the season, with a smoother peak than was anticipated. The branch crop at the end of the season was higher than normal.

The distribution of yield between 224 quarter-acre plots is shown in Table 3. The mode has moved up to the 401-600 lb. per acre class.

TABLE 3

Distribution of yield between quarter-acre plots

Yield class				Percentage of plots in each class			
				1952-53	1953-54	1954-55	1955-56
0- 200	..	..	..	5.80	11.61	17.85	12.5
201- 400	..	..	..	28.13	30.80	39.29	32.6
401- 600	..	..	..	29.91	30.36	30.36	33.9
601- 800	..	..	..	23.66	17.86	10.27	15.2
801-1,000	..	..	..	10.27	8.48	1.79	5.4
1,001-1,200	..	..	..	2.23	0.89	0.44	0.4
Highest plot yield (lb. per acre)				1,103.88	1,171.84	1,104.96	1,058.40
Lowest	..	..	..	nil	nil	nil	nil

The area from which this crop was harvested includes five-and-a-half acres of cacao for which the plots are not individually recorded. The yield of dry cocoa per acre from this averaged 440.8 lb. compared with 406.9 lb. from the recorded plots. This larger overall yield has resulted from the maturing of young cacao planted to rehabilitate areas previously affected by swollen-shoot disease.

OUT-STATIONS

Shade and density of cacao have been further reduced on all farms. Capsid damage has been severe on poorly established trees at Adonkwanta and the whole area is now being treated with BHC applied by a mist-blower. At Nankese, spray-painting with DDT has given very good control.

Yields from selected areas of well established cacao at Koransang, Kukua and Nankese are shown in Table 4. At Nankese, records were taken from forty eighteen-tree plots of cacao of uniform age, twenty under fairly dense oil-palm shade and twenty under light forest shade. The mean plot yield for the latter was 160 per cent. greater in terms of pods and 173 per cent. greater in terms of wet beans than that for the former.

TABLE 4

Yields from selected areas on Out-stations

Station	Acreage	Yield in pods		Estimated yield in lb. dry cocoa per acre	
		1954-55	1955-56	1954-55	1955-56
Koransang ..	3.0	9,990	17,383	297	528
Kukua ..	5.0	26,241	28,034	469	529
Nankese ..	3.5	10,841	12,243	277	315

RELEASE OF IMPROVED PLANTING MATERIAL

F2 pods of the ten approved Upper-Amazon types have been sent to the Agricultural Departments of the Gold Coast (5,510 pods), Western Nigeria (1,281), Eastern Nigeria (1,061), Northern Nigeria (100) and the British Cameroons (800). The total of 8,752 pods for the season greatly exceeded that estimated. F3 pods of the same types, totalling 12,000, were also sent to Nigeria.

Cuttings were sent to the Gold Coast and Nigerian Departments for the establishment of clonal collections. Those of the Gold Coast are almost complete, but losses during quarantine in Nigeria have been severe, and further consignments will be needed to make up the number.

SWOLLEN-SHOOT DISEASE INCIDENCE

Tafo Station

Infection in small seedlings remained low, only two cases being found in the experimental areas of young cacao controlled by the

Agronomy Division. However, 216 trees were removed from the older plant breeding trials, twenty more than last year. The percentage of diseased trees in other areas of mature cacao was very much the same as in the previous year, on both the Old Station (where only symptom-bearing trees are removed) and the Square Mile (where 'contacts' and suspects are also cut out).

Out-stations

The twenty acres of ten-year-old cacao at Nankese still remains free from the disease. At Adonkwanta and Kukua, where there are still diseased trees on contiguous farms, infection occurs on the perimeter. Sixty-seven trees were cut out at the former, and thirty-two (including nine 'contacts') at the latter. At Koransang there has been a sudden rise in the number of infected trees discovered and cut out, from seven last year to forty-four; but a number of these showed no leaf symptoms, diagnosis being based on rounded pods. Forty-two 'contacts' were also removed. Nine infected trees were cut out at Akwadum.

WEATHER SUMMARY

TAFO STATION

Figures for 1955 compared with 18-year means

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum 18-year mean	91.5	93.7	93.1	93.7	92.2	89.1	86.9	86.4	87.9	89.7	90.5	90.6
1955	..	93	91	93	91	87	85	85	87	90	90	89
Lowest Shade Minimum 18-year mean	59.3	61.6	65.9	66.3	66.7	66.3	65.9	65.2	66.8	66.7	65.4	62.2
1955	..	58	65	66	67	69	66	67	69	68	67	54
Mean Relative Humidity 18-year mean	86.2	83.8	82.1	80.9	81.7	85.0	86.2	86.1	85.3	83.4	81.2	84.2
(9.00 GMT) 1955	..	87.4	85.1	85.3	81.7	85.8	85.6	81.7	86.0	85.9	74.9	86.9
Mean Relative Humidity 18-year mean	55.3	52.8	56.2	59.2	63.8	69.6	70.1	69.5	71.2	71.0	65.6	61.6
(15.00 GMT) 1955	..	58.9	56.9	66.4	67.7	70.7	78.4	78.0	76.2	74.5	69.1	68.1
Rainfall in inches 18-year mean	1.57	3.83	6.06	5.66	6.93	8.54	5.47	2.62	6.25	9.25	4.06	2.34
1955	..	0.58	4.94	3.19	6.98	10.49	6.81	2.57	6.44	17.95	1.73	3.77
Number of Wet Days 18-year mean	3.6	7.2	11.8	11.2	13.7	18.6	13.8	13.0	14.7	18.5	10.6	6.1
1955	4	9	16	10	17	22	18	16	21	25	11	9

Annual Rainfall figures (in inches) 1938-1955

	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	18-Year Mean
55.33	84.96	56.92	56.59	59.45	68.87	47.03	67.30	66.99	71.81	63.47	66.23	65.77	53.88	57.53	73.16	62.58			

Monthly Rainfall (in inches) and Number of Wet Days, April 1955-March 1956

Month	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Rainfall in inches	3.19	6.98	10.49	6.81	2.57	6.44	17.95	1.73	3.77	0.89	0.61	6.40
Number of Wet Days	10	17	22	18	16	21	25	11	9	2	3	13

OUT-STATIONS
Monthly Rainfall (in inches)

Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Adonkwanta	..	3.81	10.47	4.65	7.25	10.40	8.79	1.77	3.90	10.88	2.16	2.55	66.63
Akwadum	..	2.73	7.09	5.66	7.14	16.29	4.59	2.90	5.76	10.45	4.57	5.01	72.62
Nankese	..	0.43	6.95	4.36	5.59	11.61	4.47	1.55	4.42	12.50	4.26	4.01	62.30
Kukua	..	—	4.52	7.35	3.12	10.32	4.62	1.05	3.62	9.77	0.96	2.55	51.14
Koransang	..	0.39	5.86	8.90	3.01	13.05	5.29	1.45	3.31	7.88	1.52	2.69	55.61

Annual Rainfall compared with previous years

Year	Adonkwanta	Akwadum	Nankese	Kukua	Koransang
1952	..	76.01	56.44	51.37	60.28
1953	..	56.21	49.00	47.91	49.34
1954	..	60.63	54.14	53.39	53.84
1955	..	66.63	72.62	51.14	55.61

RESEARCH

The loss of senior research staff did not affect the output of research work in the period under review as seriously as might have been expected, due to the willingness with which some remaining officers have shouldered additional responsibilities. This report contains contributions from several who have left, and next year's may give a truer reflection of the staff position. The approved Research Programme as set out in the Appendix to *Ann. Rep. WACRI*, 1954-55 (p. 105) has been followed with minor modifications, mainly involving changes in emphasis. Although there are no grounds for excessive optimism or complacency, the prospects for controlling diseases and pests, particularly capsids, are somewhat brighter. It is hoped, given adequate staff, to orientate the activities of the Institute increasingly towards improving the varieties of cacao available to growers, cultural techniques, and preparation of the crop for sale.

It is unfortunate that agronomical experiments have suffered most from the staff shortage, and some of the existing ones have had to be abandoned for various reasons; but a great advance has been made during the year towards simpler and cheaper production of rooted cuttings. Continuity of work on breeding and nutrition of cacao has been maintained, and interesting results on the chemical aspects of cocoa preparation are being obtained. Work on capsids has turned more towards elucidating the mode of action and relative efficacy of different insecticides, and finding better methods of application. The need to know how the large-scale use of insecticides will affect pollination has led to the initiation of further work on pollinating insects, about which little is known. Studies on cacao viruses in the Gold Coast and Nigeria have followed similar lines to last year, but more attention has been given to testing for resistance in certain Upper-Amazon progenies. It has been shown that black-pod disease can be controlled in the Gold Coast, as in Nigeria, by fungicidal spraying, though frequent harvesting is a better control measure where incidence of the disease is low.

TAF0 STATION

EXPERIMENTAL AREAS

A—Agronomic Investigations

- A 1—Upper-Amazon Seed Multiplication Plot.
- A 2—Upper-Amazon Spacing and Pruning Experiment.
- A 3—Frequency of Harvesting Experiment.
- A 4—Transplanting Demonstration.
- A 5—*Herrania* Plot.
- A 6—Uniformity Trial, with young Amelonado Cacao.
- A 7—Amelonado Source Experiment.
- A 8—Transplanting Experiment IV—Effect of Age and Reduction of Foliage.
- A 9—Transplanting Experiment V—Effect of Age and Road Transportation.
- A10—Establishment Experiment II—Comparison of Planted and Natural Shade.
- A11—Amelonado Spacing Experiment.
- A12—Pruning of Fan Cuttings Experiment.
- A13—Establishment Experiment I—Types of Planting Material, Holing and Mulching.
- A14—Seedlings *versus* Rooted Cuttings Experiment.
- A15—*Herrania* Bulking Area.
- A16—Transplanting Experiments I and II—Superphosphate and Reduction of Foliage.
- A17 to A22—Seedling Reserves.

B—Botanical Investigations

- B 1—Clonal Collection.
- B 2—Clonal Trial III—to be planted in 1956.
- B 3—Progeny Trial IX—1954.
- B 4—Training of Fan Cuttings Observation Plot.
- B 5—Clonal Trial I—Gold Coast Selections.
- B 6—Cytogenetics Observation Plot.
- B 7—Progeny Trial VIII—1952.
- B 8—Albino Plot.
- B 9—Clonal Trial II—Gold Coast Selections.
- B10—Trinidad Introductions Area.
- B11—*Theobroma* and *Herrania* spp. Area.
- B12—Progeny Trial II—1942.

- B13—Progeny Trial VI—1943.
- B15—Progeny Trial IV—1941–44.
- B16—Progeny Trial I—1940.
- B17—Colombian Introductions Area.
- B18—Proposed Progeny Trial Area.
- B19—Seedling Growth Experiment.
- B20—Plant Breeding Nursery.
- B21—Propagators.
- B22—Clonal Nursery.
- B23—Experiment on the Subsequent Effect of Early Bearing.

E—Entomological Investigations

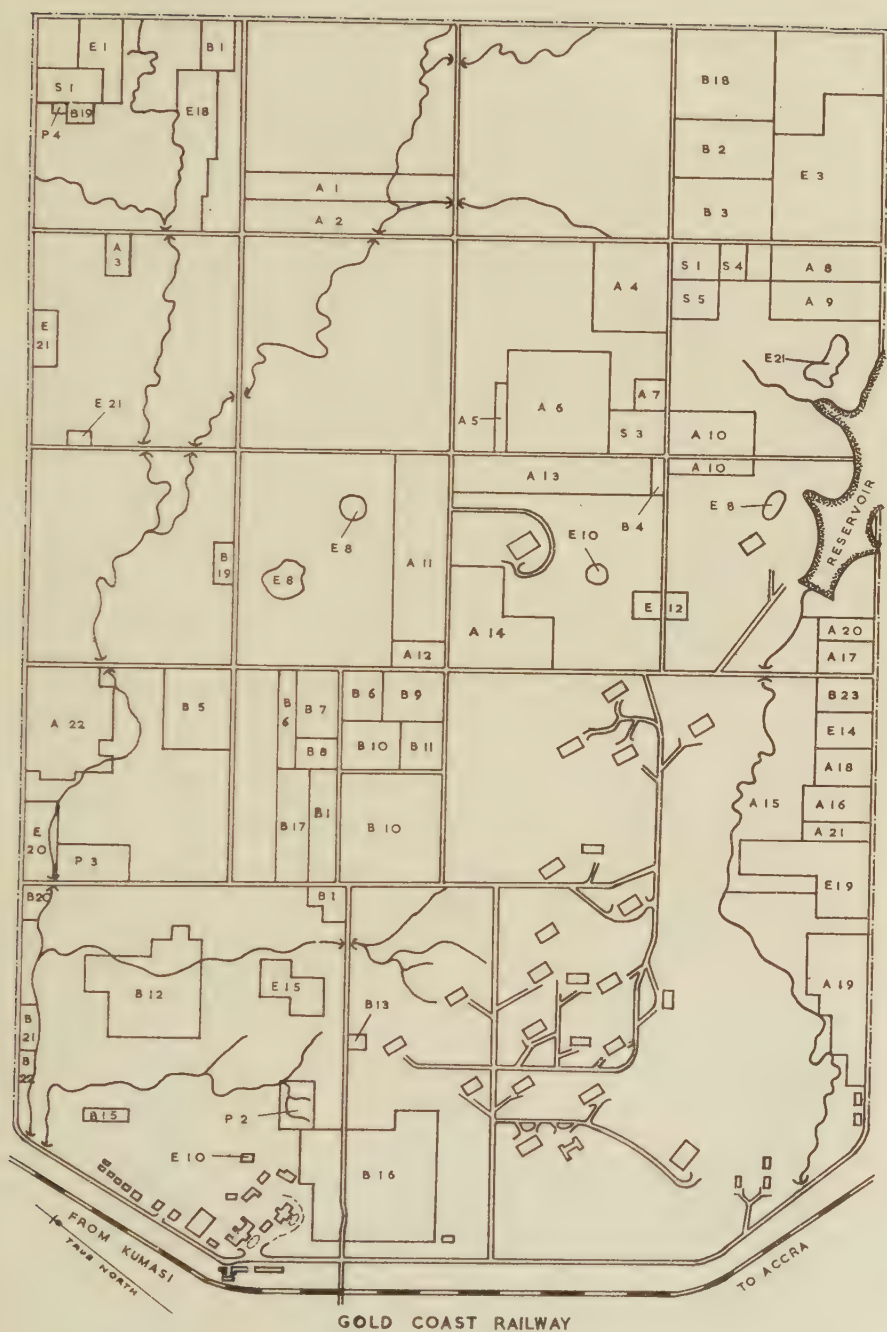
- E 1—Capsid Attack under Light or Shade.
- E 3—Insecticide Trials Area.
- E 8—Capsid Ecological Study Plot.
- E10—Light-trap for Capsids.
- E12—Capsid-pocket Regeneration Demonstration Area.
- E14—Capsid Control Experiment—Dusting and Pruning of Seedling Cacao.
- E15—Capsid Control Costing Trial—Dusting and Pruning Method.
- E18—Capsid Population Experiment—Egg Counts (1).
- E19—Capsid Population Experiment—Egg Counts (2).
- E20—Capsid Population Experiment—Egg Counts (3).
- E21—Coppicing Experiment.

S—Soil-fertility Investigations

- S1—NPK Experiment, on young seedling Cacao.
- S3—Mineral and Organic Manures Experiment, on coppiced Cacao.
- S4—Effect of Forest Litter Experiment, on young seedling Cacao.
- S5—Establishment Experiment IV—Mineral Fertilizers, Mulch, and Irrigation.

P—Pathological Investigations

- P2—Studies on Susceptibility to Black-pod Disease.
- P3—Swollen-shoot Disease Alternative Hosts Nursery.
- P4—Collection of material showing tolerance or resistance to Swollen-shoot Disease.



VIRUS RESEARCH

THE HOST RANGE OF CACAO VIRUSES (W. T. Dale and A. Attafuah)

Laboratory tests

The testing of relatives of cacao for susceptibility to its viruses has been continued. Various exotics have been tested as well as native species. It is hoped, in this way, to find out within which genera or tribes of the different families susceptibility can be expected, and how far the viruses can be grouped according to their host ranges. The following species additional to the twenty-five recorded in *Ann. Rep. WACRI*, 1954-55 (Table 5, p. 33) have been experimentally infected, using mealybugs, with one or more of the viruses (plants marked by an asterisk* being exotics):

BOMBACACEAE—*Ceiba pentandra* Gaertn. x *C. guineensis* A. Chev. (including cultivated types of kapok); MALVACEAE—*Wissadula amplissima* var. *rostrata* R. E. Fries (a common native herb or subshrub); STERCULIACEAE—**Abroma augusta* L.f. (a fibre crop), **Sterculia alata* (from Ceylon), **S. appendiculata* K. Schum. ex Engl. (from Tanganyika), **S. laevis* Wall. (from Malaya), **S. rubiginosa* Vent. (from Singapore); TILIACEAE—**Heliocarpus popayanensis* H.B.K. (from Trinidad), which is susceptible to at least six Gold Coast and Nigerian isolates.

The following species in addition to those listed previously (*loc. cit.*) have given no evidence of susceptibility to any of the viruses so far:

MALVACEAE—*Hibiscus cannabinus* L., *H. micranthus* L., *H. owariensis* P. Beauv., *Malvastrum coromandelianum* (L.) Garcke, *Sida acuta* Burm. f., *S. alba* L., *S. cordifolia* L., *S. stipulata* Cav., *S. veronicifolia* Lam., *Urena lobata* L.; SCYTOPETALACEAE—*Scytopetalum tieghemii* Hutch. & J. M. Dalz.; STERCULIACEAE—*Cola reticulata* A. Chev., *C. heterophylla* Schott & Endl., *C. laurifolia* Mast., *C. umbratilis* Brennan & Keay, **Dombeya angulata*, *D. buettneri* K. Schum., **Hermannia candicans* Ait. var. *discolor*, *Leptonychia pubescens* Keay, *Octolobus angustatus* Hutch., **Sterculia caribaea* R. Br., *S. elegantiflora* Hutch. & J. M. Dalz., *S. foetida* L., *S. oblonga* Mast., **Sterculia* sp. (*indet.*, from Bechuanaland), *Waltheria indica* L.; TILIACEAE—**Ancistrocarpus bequaertii* De Wild., **Apeiba tibourbou* Aubl., **Berrya ammonilla*, **Cephalonema polyandrum* K. Schum., *Clappertonia ficifolia* (Willd.) Decne., *Desplatsia subericarpa* Bocq., *D. chrysochlamys* Mildbr. & Burret, *Grewia flavescens* Juss., *G. lasiodiscus* K. Schum., *G. megalocarpa* Juss., *G. mollis* Juss., *G. pubescens* P. Beauv., **G. similis* K. Schum., *G. villosa* Willd., **Tilia platyphyllos* Scop., *Triumfetta eriophlebia* Hook. f.

Testing of other species is in progress. It may be mentioned here

that *Cola lateritia* and *Theobroma microcarpa* were misspelt in the last Annual Report (*loc. cit.*) due to typographical errors.

The search for natural infections

In order to find out more about the distribution of viruses in the baobab (*Adansonia digitata* L.) and their possible connection with those of cacao, over 1,000 of these trees have been examined by the Gold Coast Department of Agriculture or ourselves. Those regarded as suspicious by officers of the Department were visited by us, and tested for infection when this was considered desirable. More than 700 of the total trees examined were in cacao-growing areas, though usually near villages; some 264 were in Ashanti, 206 in the Eastern Province, 95 in the Western Province, and 140 in Trans-Volta or British Togoland. The remainder were in savannah country north and south of the cacao belt. Present evidence suggests that the incidence of virus infection in *Adansonia* in the Gold Coast is low, and of the sixteen specimens known to be infected only one occurred near cacao. This was a regenerating stump at Wusuta in Togoland, only about 150 yards from a virus outbreak of the Kpeve type in cacao. All the isolates so far obtained from baobabs give symptoms in cacao resembling those of the Alaparun (Nigeria) and Kpeve (Togoland) viruses; so it is possible that outbreaks in cacao, of the latter at least, originated in this tree, just as Western Province viruses have apparently come from *Cola chlamydantha* K. Schum. A more intensive virus survey of baobabs in Togoland is therefore proposed. Infections at Wasipe and Yabraso remain the most northerly of those detected so far, but relatively few trees in the Northern Territories have been examined.

Other potential wild hosts have been tested for natural virus infection during the year, mainly from the New Juaben and Akim Abuakwa areas of the Gold Coast. The species concerned and the numbers tested were as follows:

Sterculia rhinopetala K. Schum. (195); *S. tragacantha* Lindl. (13); *Hildegardia barteri* (Mast.) Kosterm.—formerly called *Erythropsis barteri* (Mast.) Ridley (11); *Cola gigantea* var. *glabrescens* Brennan & Keay (13); *Bombax buonopozense* P. Beauv. (2); *Ceiba pentandra* Gaertn. (45).

The only positive results obtained were from young growth on a stump of the last-named in a large swollen-shoot outbreak in cacao near Adawso. Three out of twenty of the cacao indicator plants developed virus symptoms of the New Juaben type. This is the first example of natural infection in *Ceiba* disclosed for several years, but as in the four previous instances (three at Tafo and one at Offa Igbo in Nigeria) there is no knowing whether the virus has spread from

Ceiba to cacao or *vice versa*. It is noteworthy that one of the Tafo infections and that from Offa Igbo were diagnosed in regenerating growth. When young seedlings of this and most other susceptible forest species are artificially infected in the laboratory, it is usual for symptoms to appear only on a few leaves. Later ones are often symptomless, and it soon becomes difficult to recover virus from the plants with mealybugs. Coppicing saplings known to be infected may occasionally cause reappearance of symptoms and/or make the recovery of virus temporarily possible. It may be that infection in mature forest trees is common but very seldom detectable, and no real danger to neighbouring cacao unless the affected specimen is cut or blown down and then starts to regenerate. *Adansonia digitata* and *Cola chlamydantha* differ from most other tree hosts in the relative ease with which virus can be recovered from them, even after lengthy infection.

INSECT-TRANSMISSION STUDIES (W. T. Dale)

Due to other activities it has not been possible to devote much time to this project. Results recorded in *Ann. Rep. WACRI*, 1954-55 (p. 35) suggested that nymphs and young adults of *Pseudococcus njalensis* Laing are equally efficient vectors of the New Juaben cacao virus. They did not support the earlier belief that equivalent infection rates were obtainable with either ten adults or thirty nymphs; but it was felt that this ratio might apply when vectors were manipulated by relatively unskilled operators, giving a bias in favour of the larger and more robust adults. Two experiments were therefore arranged, using assistants of varying experience. Source- and test-feeding times were at the presumed optima, and the insects were pre-starved (*loc. cit.*, pp. 33, 34). The virus-source plants in the first experiment were cacao seedlings in the first-flush stage, and two young adults were compared with six nymphs. All three operators obtained a higher infection rate with the latter, the combined figures being 75 and 95 per cent. respectively. In the second experiment, cacao seedlings in the second- or third-flush stage were used, and five young adults compared with fifteen nymphs. Three of the four operators obtained better results with the latter, the infection rates being 26 and 61 per cent. respectively.

The same virus has been experimentally transmitted, very occasionally, by first- and second-instar nymphs or young adults of *P. njalensis* given only ninety minutes' access to infected plants. As the insects were bred on sprouting potatoes or saplings of *Canthium glabriflorum* Hiern., both insusceptible to the virus, there was no chance of prior contamination.

The cacao virus isolate from Peki has been transmitted, though to

a low proportion of test plants, by both *P. njalensis* and *Planococcus citri* (Risso). *P. kenya* (Le P.), which seems to be rare in the Gold Coast (*Ann. Rep. WACRI*, 1952-53, p. 22) but much commoner in Nigeria (*Ibid.*, 1954-55, pp. 102-3), is an efficient vector of the New Juaben and Kpeve viruses.

CLASSIFICATION OF VIRUS ISOLATES (A. Attafuah and W. T. Dale)

Mild-strain protection as a control measure

In an account of studies on the New Juaben (1A) complex carried out several years ago, Posnette & Todd (*Ann. appl. Biol.*, **43**, p. 433, 1955) examined the possibilities of 'mild-strain protection' for the control of this devastating virus, a topic also discussed in *Ann. Rep. WACRI*, 1953-54. In a more recent experiment, thirty-six plants were infected, as dissected beans, with a mild strain of New Juaben. Following the development of transient mild symptoms, each seedling was colonised at monthly intervals with a single adult mealybug from a virulent-strain source (in an attempt to approximate to conditions in a field outbreak). An equal number of 'unprotected' seedlings were similarly treated. After one year, twenty-seven of these and two of the 'protected' plants showed virulent symptoms; but seven more of the latter were proved by 'back-testing' with mealybugs to harbour virulent strains.

These results show that protection can be broken down in young seedlings as well as in mature trees (*loc. cit.*), and without recourse to coppicing. Although the destructive effect of virulent strains is normally largely alleviated by prior infection with related mild ones, the former can establish themselves in the trees concerned and be transmitted readily to others. This is probably the most potent of the various arguments against mild-strain protection as a control measure.

Protection as a criterion of relationship

No further positive evidence has been obtained, from protection tests, of close relationship between isolates from widely separated outbreaks in cacao. The Sedi Nkawie virus from Ashanti gives no protection against that from Mampong in the Eastern Province, and is therefore not closely related to it. Although all three fail to produce swellings in cacao, the Kpeve (Togoland) virus is not closely allied to those from Alaparun or Asalu in Nigeria; nor to that from Yakasse in the Ivory Coast, which gives similar leaf symptoms to those of Kpeve but produces swellings.

Tests between the last-named and certain isolates from *Adansonia* (AD.7, 14 and 36) are of particular interest in view of the observations reported earlier in this report, but have so far given inconclusive

results. This is because of marked symptom similarities, which suggest relationship whilst making it impossible to be certain whether protection has occurred or not. Although the baobab isolates (AD.36 in particular) give leaf symptoms milder on the whole than those of Kpeve, this itself produces symptoms differing in virulence on Amelonado, suggesting the existence of mild strains such as are known to exist for New Juaben (Posnette & Todd, *loc. cit.*). The three baobab viruses are not related to cacao isolates from Bisa, Mampong and New Juaben (Gold Coast, Eastern Province). Amongst the naturally occurring viruses of *Cola chlamydantha*, that from Anibil is not closely related to the ones from Aiyim and Bakukrom.

Symptomatology

Symptom sequences are being carefully followed in batches of Amelonado cacao seedlings infected, as dissected beans, with sixteen Gold Coast or Nigerian cacao-virus isolates. There are marked differences in virulence, which are being assessed by leaf counts, leaf product (length $\times$ breadth) measurements, and height measurements. It is a simple matter to distinguish viruses such as Kpeve and Bisa (Posnette, *Ann. appl. Biol.*, **34**, p. 388, 1947) but more difficult to separate some of those producing both swellings and leaf patterns. Differences are noticeable but sometimes hard to describe concisely. The acute and chronic ('fern-leaf') phases of infection with New Juaben have been described by Posnette (*loc. cit.*). Bosomuoso, a Western Province virus, resembles it, but seems to have a less severe effect. Of three other viruses from there, the ones from Amafie and Wiasi cause relatively slight stunting, the latter in the chronic phase giving only mild symptoms or none, while Aiyiboso is characterised in the acute phase by pronounced banding of the finer veins, giving a bold chlorotic network over most of the leaf. Mampong (Eastern Province) produces marked whitish interveinal chlorosis initially, but infected plants commonly develop some symptomless flushes afterwards. Symptoms of Bosumtwi (Ashanti) include rather wider red vein-banding of flush leaves than is associated with most other isolates and broad 'fern-leaf' patterns in the chronic phase.

Asijere, one of the four Nigerian viruses studied, is unusual in the poor development of red vein-banding. It appears to be a complex of strains which differ in virulence (compare Posnette & Todd, *loc. cit.*), some causing severe leaf abscission and even death. Offa Igbo gives leaf symptoms not unlike those of New Juaben, though milder, and produces swellings more commonly. Olanla and Ilesha, although from rather widely separated localities, have already been shown by protection tests to be related (*Ann. Rep. WACRI*, 1954-55). The latter commonly produces severe chlorosis with abscission of leaves in the

acute phase, and marked stunting; but strains giving milder symptoms similar to those of Olanla seem to be intermixed.

No leaf symptoms associated with cacao virus outbreaks have been recognised in the Peki area; but when a virus from Peki Tsame Agato was experimentally transmitted to young plants by grafting, or to dissected beans by vectors, faint red-veining and fine chlorotic-flecking sometimes appeared on a few of the leaves developing soon after infection. Thereafter no further symptoms except swellings were produced. These were smaller than those of Bisa, which is a similar virus also producing, at most, only transient leaf symptoms. Other cacao viruses of this type occur in the Gold Coast and in Nigeria (e.g., at the Ibadan Native Administration farm).

MECHANICAL TRANSMISSION (E. Margaret Holden)

Table 5 is a summary of experiments made in an attempt to transmit cacao virus mechanically. These were aimed at finding a better source of inoculum and a more suitable test plant than cacao. Two reducing agents, thiomalic acid and cysteine hydrochloride, and two buffers, phosphate and citrate, were tested as extracting agents.

TABLE 5
Attempted mechanical transmission

Source of inoculum	Extracting fluid		Plants inoculated
	Buffer	Reducing agent	
Leaves from seedlings of <i>Theobroma microcarpa</i> or <i>Cola lateritia</i> (1 g./5 ml. soln.)	M/5 phosphate pH 7	Thiomalic acid 0.05%	Cowpea seedlings 1 week old
Leaves from seedlings of <i>Cola lateritia</i> (1 g./20 ml. soln.) ..	„	„	Cacao seedlings 5 weeks old
Leaves from cacao seedlings 3-4 months old (1 g./20 ml. soln.)	„	Cysteine hydrochloride 0.1%	French-bean seedlings 1 week old
Mature leaves from old diseased trees (1 g./20 ml. soln.) ..	„	Thiomalic acid 0.05%	„
„	M/10 sodium citrate pH 6.5	Cysteine hydrochloride 0.1%	* Cacao, * <i>Adansonia digitata</i> , † cowpea, <i>Cola gigantea</i> and <i>Sterculia rhinopetala</i> seedlings

* Four weeks old. † Six days old.

Extracts were prepared by grinding leaves in a mortar with buffer solution and a reducing agent to prevent oxidative changes in the

macerated tissue. The fluids and the mortar were chilled in a refrigerator before use and extracts from both healthy and infected leaves were inoculated to test plants as rapidly as possible after preparation. Inoculations were made by rubbing extracts on leaves of the test plants, with celite as abrasive, followed by thorough rinsing with water. On both occasions when cacao seedlings were used as test plants considerable scorching of the leaves occurred with both healthy and infected leaf extracts. There were no transmissions in any of the experiments.

A method described by Yarwood (*Plant Dis. Reprtr*, **37**, p. 501, 1953), which he used successfully for transmitting a virus of apples, has been tried, with modifications, on cacao. Discs from leaves of young seedlings infected by the New Juaben or Kpeve cacao viruses were cut out with a cork borer, stacked on top of each other, trimmed to a straight edge with a razor blade and immediately rubbed on the leaves of test plants. These were young cacao and tobacco seedlings, which had their leaves sprayed with K_2HPO_4 and dusted with celite before rubbing with the discs. There were no transmissions.

CHEMICAL DETECTION OF CACAO VIRUS INFECTION (E. Margaret Holden)

A paper has been prepared for publication on chemical aspects of the Tinsley-Usher colour test (*Nature, Lond.*, **174**, p. 87, 1954) and the following account is a summary of the results of this investigation.

Paper partition chromatography, with various solvent systems, has been applied to the separation of the 'tannin' components of cacao-leaf extracts. The substance present in the extracts which gives a red colour on heating with alkali can be separated with the alcohol layer of a butanol—acetic acid—water mixture (4 : 1 : 5) and has the reactions of a leucoanthocyanin. Attempts to separate this on a larger scale by the use of a column of cellulose powder have so far been unsuccessful.

The leucoanthocyanin is present in leaves of all ages and varies directly with the 'total-tannin' concentration. In flush leaves, which have a high 'tannin' content, it is present in sufficient amount for the colour-test score to be always high. In mature leaves the score is high if they are infected, when there is usually a higher tannin content than in comparable virus-free leaves; but if for any reason the tannin content of the latter is high, they too will have a high score. Leaves from healthy trees of some Upper Amazon selections (such as T72, T73 and T76) always give high scores because their 'tannin' content, and thus the amount of the red-producing leucoanthocyanin, is higher than in Amelonado leaves.

Some flavonoid pigments (anthoxanthins) give a red colour on treatment with alkali, and in separating polyphenolic constituents of

the cacao leaf particular attention was paid to the compounds of this class which were present. None of these appeared to play more than a small part in the colour changes of leaf extracts when heated with alkali. However, since nothing was known of the anthoxanthins of cacao leaf, and there was a possibility that differences between healthy and diseased leaves might be found, these compounds have been studied in some detail. Chlorogenic acid, which although not an anthoxanthin has some of the same reactions, has been identified in leaf extracts and also in extracts of beans from T9, a Trinitario cacao, but not from Amelonado. Further work is necessary before the other anthoxanthins can be identified with any certainty. There are no obvious differences between those of healthy and virus-infected leaves.

A colour test based on the reduction of 2, 3, 5-triphenyl tetrazolium chloride, which has been used elsewhere for detecting virus infection in other plants, has been tried on cacao. Virus-infected material is said to reduce the colourless salt to the red form more rapidly than healthy, and the reaction has also been used as a viability test for plant tissue. As a virus test, it appears to depend on a higher level of dehydrogenase activity in infected material than in virus-free. Sections from the stems of healthy and infected seedlings of various ages and from twigs of healthy and infected mature trees were compared. The results were completely erratic and it is clear that the test is not applicable to cacao.

RESISTANCE AND TOLERANCE (W. T. Dale)

Of 394 T17 (Iquitos-type) beans, derived from hand pollinations, dissected and colonised each with forty nymphs of *Pseudococcus njalensis* from plants infected by the New Juaben virus (*Ann. Rep. WACRI*, 1954-55, p. 44), 119 (30 per cent.) developed into symptomless seedlings from which no virus could be recovered and therefore presumably uninfected. The percentages for individual progenies and Amelonado controls (10 per cent.) have already been recorded (*loc. cit.*). Unfortunately, a second colonisation of each uninfected plant with 200 vectors proved too drastic, none escaping infection. Though this conclusively demonstrates lack of immunity in the progenies concerned, it makes the selection of any material showing promise of worth-while resistance to infection dependent on the establishment of virus-free budlings or cuttings from infected plants. This may be possible, even without recourse to heat treatment of propagating material (as successfully employed with an increasing number of other diseases), because the virus is apparently incompletely systemic (*loc. cit.*, p. 40, para. 4); though this evidence was obtained using

bark-grafts without buds and the latter, essential for further scion growth, may be less commonly (if ever) virus-free.

The plants were classified into categories on the basis of tolerance, for which there was obvious genetical segregation, and the data are incorporated in Table 6. Some, with marked symptoms and stunted growth (Tolerance Rating O), seemed almost as severely affected as Amelonado; others had symptoms of intermediate severity, including large swellings and mild leaf symptoms or marked leaf symptoms with or without small swellings (1); many had mild though quite obvious leaf symptoms and/or small swellings (2), and the remaining few had evanescent or hardly detectable leaf symptoms only (3), or none at all (4). Only plants in Categories 2, 3 and 4 have been retained for further investigation.

Although the initial colonisation of the 'twinned' seedlings (*loc. cit.*, p. 44) with 150 nymphs also proved unduly drastic, leading to the infection of all but five out of 188, this is not serious because most of the uninfested 'twins' are available. The infected plants have been classified for tolerance, as before, and these data also are incorporated in Table 6. Some plants with intermediate symptoms and all those showing milder effects have been retained, with the corresponding 'twins', for further study. It is not proposed to subject any of the virus-free material to further resistance testing until the plants have grown large enough for propagation as single-leaf cuttings. By 'bombarding' cuttings from appropriate selections it should then be possible to establish whether there are real differences within and between these progenies as regards resistance; and if so to what extent this is correlated with tolerance, as for some other virus diseases. The danger of tolerance, unaccompanied by a high level of resistance, as a control measure has been already pointed out (*loc. cit.*, p. 45). It would be mitigated, however, if reduced availability of virus to vectors proved to be associated with lack of symptoms, and the remaining infected 'twins' will be used to test this. The number of Amelonado indicator plants infected during the 'back-testing' of symptomless carriers was not encouraging in this connection; furthermore, these indicators showed the usual virulent symptoms, so passage through tolerant hosts seems to have no effect on the virus. Amongst the 'twins' were the progeny of an open-pollinated pod of WBE 980, a hybrid between T16/613 (Iquitos-type) and an E1 (local-hybrid) derivative. These showed no evidence of resistance or marked tolerance.

TABLE 6

Tolerance to the New Juaben Virus

Progeny	Plants tested	Tolerance Rating of infected plants (see text)					Apparently healthy
		0	1	2	3	4	
T17:							
1,070 × 447	39	9	9	17	4	—	—
„ × 1,219	45	3	9	32	1	—	—
1,072 × 357	43	25	6	11	1	—	—
„ × 358	38	9	6	22	1	—	—
„ × 433	98†	27	15	54	—	2	—
1,131 × 1,157	51	18	15	15	3	—	—
„ × 1,159	43	15	4	21	2	1	—
„ × 1,220	37	14	7	15	1	—	—
1,070 × 434	48*	23	10	11	—	2	2
„ × 447	38*	8	16	11	2	0	1
1,072 × 521	40*	1	9	19	5	6	—
1,131 × 1,217	31*	11	10	6	—	2	2
WBE 980	31*	12	17	2	—	—	—
Amelonado controls	45 83*	Unclassified—in general more severely affected than the above.					—

* Tested once as seedlings; the others tested as beans and re-tested as seedlings where no evidence of infection.

† Beans from two pods of the same parentage.

Preliminary results from the trials discussed above indicated the necessity for studies on the parent (F₁) T17 trees themselves. These were derived from an open-pollinated pod from a tree established in Trinidad. Thus, although the female parent was of Iquitos origin the male was unknown, though probably of Upper-Amazon type. Fifty of the fifty-three F₁ trees, including all the parents of progenies in Table 6, were chosen to provide rooted cuttings for a resistance trial, five per replicate being taken from each tree. The first replicate is now complete and three more are in progress. Due to varying supplies of suitable material from tree to tree and differences in ability to root, it was not possible to test all cuttings in a particular replicate at the same time, but care was taken to ensure that all were at the same stage. In the first, second and fourth replicates testing was done when the first flush (on which the mealybugs were put to feed) was still tender; in the third it was mature. Fifty nymphs of *P. njalensis* per plant were employed throughout, after twenty-four hours on young virus-source plants which were as uniform as possible. Due to the size of the experiment several people were responsible for manipulating vectors, but all are experienced so there should be little variation on this account.

In the first replicate, sixteen of the 250 cuttings failed to become

infected. The virus-free cuttings are distributed amongst the following eleven lines, as indicated by the bracketed numbers:

T17/1219b, 2626 (3); 448b (2); 359a, 434b, 1130a, 1132a, 1159b, 2628, 2651, 2655 (1).

The performance of these in subsequent replicates is awaited with interest. It has been shown by the Plant Breeders that the WACRI T17 trees appear to fall into two groups, the members of which are incompatible amongst themselves but compatible with those of the opposite group. Three of the above lines, marked (a), are known to belong to one group and four (b) to the other, a reassuring indication for future breeding work. T17/434, 1159 and 1219 are male parents of some of the hybrids already tested. It is not surprising to find apparent segregation for resistance amongst these hybrid F₁ trees, and it may be expected to occur in the F₂ generation derived by crossing them (see above).

Although the cuttings are showing obvious differences in tolerance it is too early yet for a final classification to be made. There is a suggestion that tolerance and resistance may segregate together.

A few plants of Nanay parentage which remain uninfected after tests carried out by Posnette & Todd (*Ann. appl. Biol.*, **38**, p. 785, 1951) are being propagated as cuttings for comparison with Iquitos-type progenies. Attempts are also being made to obtain virus-free material from a few other infected Nanay plants which have shown a high degree of tolerance.

All the work carried out so far has been concerned with resistance to the New Juaben virus. There is no certainty that varieties resistant to this would be so to other unrelated cacao viruses. A replicated trial with rooted T17 cuttings, comparable with the one described above, has been started to investigate resistance to the Kpeve virus, one of those apparently most distantly related to New Juaben.

MEALYBUG STUDIES

MOVEMENT OF MEALYBUGS IN AND BETWEEN CACAO TREES (P. B. Cornwell)

There is marked uniformity in the composition of the mobile population of mealybugs, *Pseudococcus njalensis*, on infested cacao trees; over 90 per cent. are first-instar nymphs and less than 2 per cent. are adults. Live adults are very occasionally carried in the mouths of Crematogasterine ants but the movement of nymphs in this manner has not been recorded. It is not known whether the mobile first-instar nymphs feed before leaving their colonies, so their significance

as potential vectors of swollen-shoot virus diseases cannot at present be assessed. Further work should be directed towards studying mealybug movement on diseased trees and testing mobile insects for infectivity. Moving mealybugs were recorded at all levels on trees, from one foot above the ground to the tips of canopy branches. The distributions of the mobile and static populations are closely related, with some 85 per cent. of both occurring in the canopy.

Changes in the numbers of mobile mealybugs recorded on cacao trees over a period of four months showed a very close correlation ($r=+0.73$; $P=0.001$) with temperature. There was a less marked though statistically significant positive correlation with the number of hours of sunlight, but not with changes in evaporating capacity of the air. There are marked changes in mealybug movement during the day; it starts at noon, after which there is a very rapid increase in activity to a maximum at about 3 p.m., followed by a decline towards 6 p.m. Whilst these variations are positively related to temperature, it is considered that the major factor responsible for initiating movement is incident sunlight, which penetrates the forest-tree canopy at mid-day when the sun is vertically overhead. This sunlight probably produces an increase in temperature under the carton tents built over the mealybug colonies by ants. Once they are out of the tents, mealybug movement is probably controlled by atmospheric temperature.

It has been assumed that the growth habit of farmers' cacao in the Gold Coast, with its interlocking branches, is ideal for the movement of vectors from one tree to the next, and consequently for the spread of viruses. Using mealybugs 'labelled' with radioactive phosphorus (P_{32}) it has been possible to show, conclusively, that they are indeed capable of moving from tree to tree through the canopy. This result was achieved by the release of mealybugs from radioactive seedlings tied amongst the foliage of a tree. In an attempt to radioactivate whole cacao trees for the production of labelled mealybug populations at their feeding sites in the field, P_{32} was introduced by trunk implantation, submersion of roots or application through the soil. The most uniform distribution of radioactivity in the tree was obtained by the last method. It was shown that the distribution of tracer in the trunk and branches was influenced by the positions of the implantation holes, or of the roots engaged in absorbing active material. There is little lateral movement in the conducting vessels of the trunk, so that only those branches which originate near the translocation stream take up P_{32} . During this work radioactive mealybug populations were obtained, but the distributions and levels of activity in the branches were not suitable for labelling populations for ecological studies. The results are, however, of interest in relation

to the application of systemic insecticides, the possible use of labelled nutrients in fertilizer studies, and studies on the effect of shade.

The growth habit of plantation cacao, as regards spread of the canopy, number of terminal branches and percentage of these in contact with adjacent trees, has been studied in the Amelonado Spacing Trial (see experiments on establishment and maintenance). This was planted in 1947, so the results are applicable only to eight-year-old trees. The mean spread of the canopy of trees planted between the limits of 4 and 15 ft. apart was shown to vary between 8 and 11 ft. The number of terminal branches increased in a sigmoid manner from about twenty at the 4 ft. spacing, to about fifty-five at 7½, 10 and 12 ft., and to eighty at 15 ft. The percentage of these branches touching adjacent trees decreased from 40 per cent. at 4 ft. spacing to zero at 12 ft. Such factors would be expected to influence mealybug movement between trees at different spacings and observations to test this have been made, but complete results are not yet available.

A more detailed account of these preliminary experiments on the movement of mealybugs in and between cacao trees has been prepared for publication.

EFFECT OF WIND CURRENTS ON VECTOR DISPERSAL (P. B. Cornwell)

Using apparatus of limited sensitivity, a study was made of the vertical pattern of wind movements in farmers' cacao. Mean daily wind speeds, measured from 2 to 30 ft. above the ground, varied between 25 and 850 ft. per hour. This range indicates that highly sensitive equipment is required to enable a critical study to be made. However, using a fan anemometer coupled to a directing vane, it was shown that wind movement at different levels is greatly influenced by the condition of the cacao canopy. Catches of air-borne mealybugs on adhesive traps at various levels under closed and open canopies (*Ann. Rep. WACRI*, 1954-55, p. 46) were shown to be closely related to the pattern of wind movements. Results from various experiments using adhesive and seedling traps to sample populations of air-borne mealybugs have emphasized that future work should involve the use of suction traps. Preliminary work was started using 6- and 9-in. 'Ventaxia' suction fans, but the small size of the insects was a limiting factor in the examination of catches. All other experiments on these lines described previously (*loc. cit.*) have been terminated, and the results will be considered collectively in a paper which is at present in preparation.

ANT-MEALYBUG RELATIONS (P. B. Cornwell)

Continued use has been made of three light-traps to investigate

whether ants carry mealybugs during mating flights, but no further mealybugs have been recorded. This experiment will terminate in May 1956.

MASS-BREEDING OF MEALYBUGS (F. E. Decker)

Large numbers of mealybugs are required for bionomical studies and virus research both in the Gold Coast and Nigeria, but the existing method of obtaining supplies by field collection has its drawbacks. At Tafo, quite a large labour force is needed to ensure that sufficient are available, while at Ibadan the virtual absence of cacao near to the Sub-station and generally lower population levels of the insects compared with the Gold Coast combine to make matters even more difficult. Furthermore, the risk of collection from virus-infected trees, particularly at Tafo, means that in virus research many mealybugs must be expended on control tests; and even then the results of critical experiments cannot always be accepted without reserve. A satisfactory method of mass-breeding mealybugs would thus be extremely useful.

As a preliminary to the development of a successful technique a 'culturing room' was built, in which attempts were made to maintain a high relative humidity simulating field conditions. It was found that a relative humidity of about 95 per cent. and a temperature around 84°F. could be maintained over a fairly long period. Under these conditions rapid germination of cocoa beans was obtained, and the resulting seedlings grew satisfactorily at first. They were infested with 'crawlers' and adults of *P. njalensis*, care being taken not to introduce parasites and predators. Adult mealybugs were placed between the cotyledons of some cocoa beans before planting, but after germination the plants were found to be mealybug-free. On infested seedlings, however, colonies built up rapidly; but in the absence of ants they soon became smothered by moulds which developed on the honeydew. Attempts to establish attendant ants of the genera *Crematogaster* and *Pheidole* were unsuccessful, these showing no apparent interest in the bugs. Moreover, due to inadequate illumination aggravated by mealybug feeding, the plants became chlorotic and later shed their leaves.

It is evident that the success of a technique for the mass-rearing of mealybugs is dependent on providing favourable conditions for host plants, mealybugs and associated ants. Such conditions were apparently not obtained in this initial trial.

In subsequent attempts, potato tubers were used as host plants for the mealybugs and particular attention was paid to creating ideal conditions for the establishment of attendant ants. To this end the 'culturing room' was made more airy by fixing wire gauze in the

window in place of the original glass. Records of temperature and relative humidity taken four times a day over a period of months showed remarkably little variation around means of 77°F. and 94 per cent. respectively. Successful establishment of both *Crematogaster* and *Pheidole* ants was achieved under these conditions. The ants, which were first fed on a 55 per cent. sugar solution, readily transferred their attention to mealybugs as soon as colonies developed on the host plants. So far, the limiting factor in the establishment of mealybugs has been the difficulty of providing favourable conditions for the sprouting potatoes. Treatment with Perenox before planting almost entirely eliminated tuber-rot, but the spindly sprouts which developed have been liable to tip-rot and incapable of supporting heavy mealybug colonies for any appreciable length of time. Nevertheless, the 'culturing room' has provided a useful if small supply of mealybugs for critical transmission experiments, in which it was imperative that any chance of prior contamination with virus should be eliminated. Further improvement in the breeding technique is contemplated.

BLACK-POD DISEASE

(A. L. Wharton)

SPRAYING AND HARVESTING TRIALS

Following the poor results given by fungicidal sprays on Trial I over the first year (*Ann. Rep. WACRI*, 1954-55, pp. 49-55), the trial was re-designed in March 1955. In its original form (a $3 \times 3 \times 2 \times 4$ split-plot factorial lay-out) more plots were left unsprayed (as controls) than were allocated to each spray; now the numbers of plots for each treatment have been equated by changing to a $4 \times 2 \times 2$ lay-out. The frequencies of application for the three fungicidal sprays (Perenox, Bordeaux mixture made with calcium carbide and ordinary Bordeaux mixture made with lime) were changed from monthly and bi-monthly to monthly and 'frequent'. This latter rate of application involved a spray schedule based on the seasonal incidence of black-pod disease (*Phytophthora palmivora* Butl.) and included weekly or fortnightly spraying during the mid-crop season, when the disease is most prevalent, and monthly spraying before and after this period. The original monthly and bi-monthly sprayed plots were split to receive the two new levels of application. The sixteen 'spare' control plots released by altering the design provided trees with two years' harvesting records for cushion-infection studies on this trial area (see below).

All the measures tested in Trials I and II for controlling black-pod disease have, in the year under review, given successful results, though to differing extents. It is proposed to continue Trial I for a further season to confirm the results obtained, and at the same time to try and cut down the costs of certain treatments by reducing their frequency. Trial II, which could not be expected to give much more information, has now been terminated.

Yields from both trials for the entire 1955-56 crop season are summarised in Table 7. Weights of beans recovered from pods in the various categories are not included, additional information given by such figures being briefly summarised in the text.

TABLE 7
Trials I and II: yields for 1955-56

<i>Fungicide and trial</i>	<i>Frequency of application</i>	<i>Frequency of harvesting</i>	<i>Total pods per tree</i>	<i>Un-damaged %</i>	<i>Black pods %</i>	<i>Rodent damaged %</i>	<i>Others damaged %</i>
Unsprayed (Trial I)	—	Weekly Monthly	57.8 35.7	56.0 39.5	20.4 35.2	16.6 19.1	7.0 6.1
Carbide-Bordeaux mixture (Trial I)	*Frequent	Weekly	53.5	71.1	5.2	18.9	4.8
		Monthly	33.4	78.3	5.7	11.3	4.7
	Monthly	Weekly	46.6	77.3	6.4	11.0	5.3
		Monthly	41.7	54.8	11.5	27.9	5.8
Ordinary Bordeaux mixture (Trial I)	Frequent	Weekly	61.1	74.6	6.7	14.0	4.6
		Monthly	64.6	56.8	11.0	24.0	8.2
	Monthly	Weekly	52.9	61.6	9.5	20.7	8.2
		Monthly	48.3	61.2	15.4	17.4	6.0
Perenox (Trial I)	Frequent	Weekly	57.1	66.8	6.4	20.5	6.3
		Monthly	34.8	64.9	11.9	17.8	5.4
	Monthly	Weekly	42.0	63.2	12.7	20.4	3.7
		Monthly	31.2	61.2	17.4	16.6	4.8
Unsprayed (Trial II)	—	Weekly	34.0	67.5	17.0	11.0	4.4
		Monthly	28.1	54.5	33.1	8.9	3.4
Perenox (Trial II)	Fortnightly	Weekly	32.6	71.8	11.1	13.4	3.7
		Monthly	27.7	71.9	12.2	11.8	4.1
	Monthly	Weekly	29.6	82.2	9.1	5.5	3.2
		Monthly	30.1	57.9	24.3	13.2	4.6
Blitox (Trial II)	Fortnightly	Weekly	29.7	69.4	16.9	9.4	4.3
		Monthly	36.0	65.8	14.8	13.7	5.7
	Monthly	Weekly	21.2	72.2	16.6	8.6	2.7
		Monthly	27.7	68.3	17.1	11.3	3.2

* 24 applications per annum—weekly, fortnightly or monthly, depending on the seasonal incidence of black-pod disease.

As shown in column 4, the difference in total pods from weekly and monthly harvested plots was again pronounced (though not shown by those sprayed with Blitox). The reason for this remains obscure. Results from the frequency-of-picking experiments in the 1954-55 season (*loc. cit.*, p. 55) gave good evidence that longer intervals between pickings were associated with lower yields of total pods, but the 1955-56 figures have not supported this. The problem is sufficiently important to merit examination in greater detail. In conjunction with the Physiologist, individual trees, for which pre-treatment records are available, are being harvested at weekly and monthly intervals over the coming season and additional records kept of the number of flowers formed and set.

Weekly harvesting again reduced the number of pods attacked by *P. palmivora*, and much more so than in previous seasons. If wet-bean weights for Trial I are expressed as the weight of good beans per pod (to give a direct comparison between the weekly and monthly harvesting treatments, uncomplicated by differences in total pods) weekly harvested trees yielded 51 per cent. more than monthly on the unsprayed plots. The difference between the two treatments on sprayed plots was much lower—23, 25 and 27 per cent. for Carbide-Bordeaux mixture, ordinary Bordeaux mixture and Perenox, respectively. This is accounted for by the pronounced effect of the sprays, irrespective of the harvesting treatment. The increase in good beans by weekly harvesting was largely attributable this year to reduction in the proportion of pods attacked by the disease and not to better recovery of beans from ripe diseased pods. For all treatments on Trial I over 90 per cent. of the total beans came from undamaged pods (over 95 per cent. in nine of the fourteen treatments). The remaining beans were from 'black-pods', rodent-damaged pods and those damaged from other causes. Though more beans from pods incompletely destroyed by *P. palmivora* were in fact saved by weekly harvesting, the saving was negligible relative to the good beans from undamaged pods.

Unlike last season, spraying with copper fungicides has considerably reduced the amount of black-pod disease, even at the monthly level. It was shown then that the sprays had controlled distal pod infections (which can only have originated from spores) but not proximal (stalk-end) infections (originating from diseased cushions or spores). Distal pod infections have been further reduced this season, but the increased effect of the sprays on total black-pod infections was largely a result of the proximal infections also being controlled (see Table 8—from which 'black pods' with an unknown point of infection are excluded).

TABLE 8

*Numbers of distal (D) and proximal (P) infections in Trial I as percentages of total pods**

	<i>No spray</i>		<i>Bordeaux mixture</i>		<i>Perenox</i>		<i>Carbide-Bordeaux mixture</i>	
	<i>D</i>	<i>P</i>	<i>D</i>	<i>P</i>	<i>D</i>	<i>P</i>	<i>D</i>	<i>P</i>
Monthly application	6.85	7.13	1.97	4.12	2.68	4.59	1.20	2.30
'Frequent' application			1.39	2.25	1.55	2.29	0.72	1.46

* Compare with *Ann. Rep. WACRI*, 1954-55, p. 53, Table 9.

Recent evidence (see below) suggests that most proximal infections arise from spores lodging and germinating in the depression at the stalk-end of pods. It is difficult, using pneumatic knapsack equipment, to cover this end with fungicide satisfactorily, especially for pods high in the canopy which are 'jetted'. However, the methods of application (i.e., quantity of spray per pod, concentrations of fungicide, and equipment) have been identical throughout, and there is no reason to suppose that the proximal ends of pods, including the depression, have been sprayed any more efficiently during the second year. It has been suggested that spraying and frequent harvesting may have produced a cumulative reduction in cushion infection, thereby substantially reducing pod infection from this source. Two facts are against this. Firstly, the proportion of proximal black-pod infections has remained fairly constant. Secondly, it has been shown that few cushions produce pods in two succeeding years, so control treatments one year would not be expected to reduce the amount of pod infection from cushions in the next; though there remains the possibility of reducing infection amongst main-crop pods on cushions that have borne earlier in the season, assuming fairly rapid movement of the fungus from pod to cushion and *vice versa*. The most obvious explanation which can be offered, on present knowledge, for the improved control of proximal infections by monthly spraying, is that further reduction of distal infections has cut down the spread of inoculum between pods on the same and perhaps also adjacent trees. It is also possible that spraying was started too late in 1954-55 to prevent a build-up of inoculum early in the season, which relatively infrequent spraying was inadequate to counteract.

In Trial I, Carbide-Bordeaux mixture gave the best results, especially if applied 'frequently'. As would be expected, the lowest incidence (5.2 per cent.) was in plots harvested weekly and sprayed 'frequently', but with Carbide-Bordeaux good control was obtained

from 'frequent' spraying and monthly harvesting (5.7 per cent. incidence) or regular monthly spraying throughout the year and weekly harvesting (6.4 per cent.). Comparable control was given by ordinary Bordeaux mixture (6.7 per cent.) and Perenox (6.4 per cent.) but only when applied 'frequently' and combined with weekly harvesting. In Trial II, Perenox did not appear to give quite such good results, even when applied at regular fortnightly intervals and combined with weekly harvesting. But as the plots on this trial were scattered throughout a large block of untreated cacao, providing heavy sources of infection, a direct comparison with Trial I (where the plots are much closer with fewer unsprayed trees between) is difficult; hence the use of Perenox on both trials as a standard. Blitox was less effective than Perenox.

To summarise the trials to date briefly, it appears that weekly harvesting, apart from any possible effect on the total pods borne by a tree, has proved its effectiveness as a simple measure for improving yields (especially where existing and potential yields are known to be low) through reducing the incidence of black-pod disease. The highest level of control is attainable by a combination of weekly harvesting and fungicidal spraying, but at a greatly increased cost and thus only economic in higher yielding cacao with heavy pod losses resulting from the disease. However, as will be seen from Table 7, given an effective fungicide such as Carbide-Bordeaux mixture, the control achieved by spraying alone is such that the need to harvest very frequently is greatly lessened. On the basis of these trials only Carbide-Bordeaux and Perenox merit further consideration, the former because of its effectiveness and persistence, the latter because it combines reasonably good fungicidal properties with ease of preparation.

Rodents continued to be a major cause of pod losses and their depredations warrant serious attention. The incidence of rodent damage varied from plot to plot, but showed no obvious relation to spraying or harvesting treatments; nor did these treatments have any apparent effect on losses from other causes.

The control plots from Trial II, for which two years' pre-treatment yield records are available, are being used for a simple pilot experiment to test the effectiveness of two new copper preparations, a copper-oil emulsion (*Oleocuvire*) and a new formulation of copper oxychloride (*Wettable Blidust*). Perenox is being retained as a standard, but at 0.4 instead of 0.3 per cent.

It is worth noting here that the programme of shade reduction started three years ago by the Department of Agriculture on cacao areas at Bunso Plantations appears, this year, to have drastically reduced losses due to black-pod disease. Losses on the treated fields

were much lower than in previous years, and when compared with this year's figures for unsprayed plots on the WACRI trial areas, where the original shade has been retained.

CUSHION INFECTION

As proposed in *Ann. Rep. WACRI*, 1954-55, an experiment was started at the beginning of July 1955, to find out what proportion of proximal black-pod infections recorded on Spraying Trial I originated from diseased cushions, and how many were due, like the distal infections, to air- or splash-borne spores. Six 'spare' control plots (see above) including seventy-two trees were used. All 'accessible' pods were brush-painted weekly with a strong Perenox paste, with the object of completely preventing infections from germinating spores. Any proximal infections recorded later might then be attributed to the fungus spreading internally from the cushion. Treated pods and untreated 'inaccessible' pods in the canopy were recorded separately.

During the six-month period ending in December 1955, 2,483 pods were harvested from the seventy-two trees. Of these 1,167 came from the 'accessible' parts and had been brush-painted; eighty-one of them developed black-pod disease and in all but eight infection originated at the cushion end (one additional wound-infected pod has been ignored). Of the remaining 1,316 'inaccessible' pods that were not brush-painted 140 (10.6 per cent.) became infected, 65.4 per cent. of these from the proximal end.

By comparison with the two years' pre-treatment yields from the six treated plots, and the yield and pod-disease records (covering the three seasons from 1953 to 1956) for the nearby weekly harvested unsprayed (control) plots of Trial I, it is possible to estimate the losses from black-pod disease had the seventy-two trees not been treated. Some 37 per cent. infection (918 'black pods') would have been expected. Proximal-infection records from the treated and control plots have, over the past three years, always been between 61 and 66 per cent. of the totals. As 65.4 per cent. of 'inaccessible black pods' on the treated trees were infected proximally, it can be assumed that a very similar proportion of 'accessible black pods' would also have been proximally infected but for the treatment. Knowing the actual number of 'inaccessible black pods', it is possible from the above figures to estimate that over a full season infection from cushions on Trial I amounted to 1-1.5 pods per tree, representing 3-4.5 per cent. of total pods, 9-12 per cent. of 'black pods' and 13-18 per cent. of proximal infections. Estimates of pod infection arising from cushions given in the Fortieth Quarterly Report were arrived at without access to pre-treatment records. It was noted

there that the lower estimates were more likely to be accurate in each instance. The estimates above, which take the pre-treatment figures into account, closely agree with the lower ones in the Quarterly Report.

This experimental method of preventing spore infection by applying a heavy fungicidal paste has proved efficacious and worth repeating, with slight modification. One drawback was that by painting trunk pods with fungicide spread of the disease from pod to pod on the same tree was probably reduced, so the black-pod figures recorded for the canopy are probably slightly lower than they would otherwise have been. A second experiment has been started, which should give a more direct and precise estimate. Half the trees, which were selected at random, have 'accessible' pods painted and 'inaccessible' left untreated. To obtain accurate control figures for each of these groups the remaining trees are untreated, pods harvested from them being divided into 'accessible' and 'inaccessible' and recorded separately.

Although the indications are that pod infections from cushions are few, those that occur early in the season may play an important part in producing the inoculum to start new epidemics. Even small cherelles thus infected should not be discounted in this connection.

CAPSID STUDIES

EFFICIENCY AND MODE OF ACTION OF INSECTICIDES (F. Raw)

The toxicity, mode of action, and persistence of certain insecticides which are or might be of use for capsid control have been studied, using *Distantiella theobroma* (Dist.) as the test insect except where otherwise stated. Specimens bred in the laboratory were used as far as possible. These were obtained by caging adults on well grown Amelonado seedlings eight to nine months old, at the rate of two or three pairs per plant. After one or two days the seedlings were examined and retained in the insectary if eggs were found. On hatching, the nymphs were transferred to and reared on unripe pods suspended in ventilated glass cages.

Relative toxicity of insecticides to Capsids

The comparative toxicity of BHC and DDT to nymphs and adults was investigated by caging the test insects on pods which had been dipped into aqueous solutions of known concentration and then allowed to dry. It was found that, at concentrations hitherto used in field trials, BHC has a much higher toxicity than DDT. Using first-instar nymphs, a 50 per cent. knockdown was achieved with 0.25 per

cent. BHC as against five hours with 2.5 per cent. DDT. In later experiments, Aldrin, Chlordane and Dieldrin were compared with BHC and DDT. Pods were sprayed to drip point with the insecticides at known concentration and the deposits allowed to dry. Nymphs were exposed on the pods for known periods and then placed on clean food in Petri dishes overnight before assessing the percentage kill. In these tests BHC showed much the highest toxicity, Aldrin being apparently more toxic than the remainder.

Fumigant action of BHC and Aldrin

It has been shown that deposits of BHC and Aldrin have a strong fumigant toxicity to capsid nymphs and adults at 30–35°C. Cacao leaves were sprayed to drip point with 0.25 per cent. BHC and the spray deposit allowed to dry. Capsid nymphs and adults were then caged over the leaves without being in contact with the leaf surface. All first- or fifth-instar nymphs were killed by exposure for two or four hours, respectively, and adults by thirty minutes' exposure. Aldrin has a less powerful fumigant action, probably due to lower toxicity rather than lower volatility. No similar action has been demonstrated for DDT.

Persistence of insecticides

The persistence of DDT deposits under field conditions was first investigated using *Tribolium castaneum* Hbst. as the test insect. Deposits were obtained on cacao foliage in the field by dipping leaves *in situ* into aqueous emulsions of DDT of known strength. After the prescribed periods leaves were brought into the laboratory, where adults of *T. castaneum* were exposed on them and the percentage mortality recorded. The results of preliminary tests are given in Table 9.

TABLE 9
Percentage mortality of T. castaneum Hbst.

<i>DDT emulsion</i>	<i>Interval after spraying</i>			
	<i>1 day</i>	<i>14 days</i>	<i>28 days</i>	<i>42 days</i>
5 %	100	86	74	28
2.5 %	88	38	30	2
1.25 %	50	19	6	0

Later, the persistence of BHC was compared with that of DDT using capsid nymphs, following development of the laboratory pod-rearing technique. Leaves and pods growing under normal shade

conditions were sprayed and toxicity of the deposits assessed at intervals. The results were rather variable, but in general there was little evidence of toxicity persisting for more than four weeks, even when pods or leaves were initially sprayed to drip point. BHC deposits, though less persistent, appeared to inhibit feeding after ceasing to kill the nymphs.

Conclusions

It is concluded that insecticides giving a rapid kill are likely to be more effective for capsid control than those which may persist longer but are less toxic. The value of persistence as such has probably been over-emphasised in the past. It is considered that the fumigant action of BHC has an important bearing on its application to capsid control, and together with its higher toxicity may explain the superiority to DDT observed in field trials conducted by WACRI and the Gold Coast Department of Agriculture. When spraying mature cacao under field conditions it is virtually impossible to obtain complete cover, so the use of an insecticide with a fumigant action has obvious advantages. Aldrin merits further consideration for this reason.

EFFICIENCY OF FOG APPLICATION OF BHC (D. J. Taylor)

The demonstration of the importance of fumigant action in the control of capsids by BHC has re-opened the possibility of using a fogging method of application. Trials carried out eighteen months ago using a proprietary insecticidal solution, based on DDT, in a thermal fog generator ('Swingfog' pest-control unit) gave a very poor kill and the method was subsequently abandoned. Using the same unit and an insecticidal mixture consisting of one part BHC concentrate, containing 20 per cent. of the gamma isomer (Gammalin 20, Plant Protection, Ltd.), and three parts diesel fuel, very good results have been obtained. The recent experiments were carried out in mature cacao, using adults and nymphs of *Distantiella theobroma* as the test insects. The capsids, in 16-mesh wire-netting cages, were placed in the trees 12-15 ft. above ground-level and down-wind to the line of movement of the operator.

A 100 per cent. kill of adult capsids which were placed in the fog 10 ft. from the generator was obtained after $2\frac{1}{2}$ hours; nymphs in a similar position were dead within twelve hours. At 60 ft., a 100 per cent. kill of adults was obtained in twenty hours, and of nymphs in thirty-six hours. In an experiment to find the maximum distance at which a kill may be obtained, series of cages were set up at 60, 80, 100 and 120 ft. from the operating line. A 100 per cent. kill of adults was recorded at 60, 80 and 100 ft., twenty to twenty-four hours after the application; approximately 60 per cent. of nymphs were killed

under the same conditions. At 120 ft., only 60 per cent. of adults were dead after twenty-four hours. Thus, a reasonably good insecticidal effect can be expected up to a distance of 100 ft., though it will, of course, depend on prevailing weather conditions.

To obtain some information on the quantity of insecticide required, a fog application was made to an area of $10\frac{1}{2}$ acres of mature cacao which was in lines and at a regular spacing of 10ft. by 10ft. In order to estimate the efficacy of the application, twenty cages containing 300 capsids in all were set up throughout the area. During application the operator walked through the cacao along parallel lines at approximately 100-ft. intervals, and completed the job in thirty-five minutes; 3,320 ml. of the insecticidal mixture was used, and as this contained 830 ml. of the BHC concentrate, 79 ml. of concentrate was used per acre. Twenty-four hours later a 68 per cent. kill of adults and a 31 per cent. kill of nymphs were recorded. A similar trial was carried out later through the same area, in which the operator walked along parallel lines at approximately fifty-foot intervals. This application took fifty-five minutes and 6,065 ml. of the insecticidal mixture was used, equivalent to 144 ml. 20 per cent. BHC concentrate per acre. After twenty-four hours a 95 per cent. kill of adults and a 43 per cent. kill of nymphs were recorded. The quantity of concentrate used compares favourably with the 568 ml. (4 oz. gamma BHC in five gallons per acre) used in the low-volume liquid application of the large-scale spraying operations of the Gold Coast Department of Agriculture.

Thus it appears that fog application of BHC is a very effective and economical method of capsid control for large areas of mature cacao, because of the rapidity with which it can be effected and the very efficient conversion of the concentrate to a widely dispersed and highly toxic form.

COMBINED CULTURAL AND INSECTICIDAL CONTROL OF CAPSIDS

(D. J. Taylor)

Experiments were designed (*Ann. Rep. WACRI*, 1954-55, p. 64) to investigate the possibility of controlling capsids, on regularly spaced uniform cacao, by combining an insecticidal treatment with routine cultural operations, which would include removal of all chupons after formation of the first jorquette. This chupon pruning encourages the formation of a low canopy and a laterally branching tree. It is practised in the cacao plantations of the Belgian Congo, and combined with an insecticidal dust application has resulted in the virtual elimination of capsids as pests. In our experiments a comparison is being made, on pruned and unpruned cacao, between localised application of 5 per cent. DDT dust to trees on which recent damage

is found and thrice yearly application of 1.25 per cent. DDT aqueous emulsion to all trees, using the spray-painting technique (*Ann. Rep. WACRI*, 1953-54, p. 16).

The first experiment was laid down at Tafo in 1954 on young Amelonado cacao spaced at 8 ft. by 8 ft. The four treatments were: (i) spray-painting of unpruned trees; (ii) spray-painting of chupon-pruned trees; (iii) dust application to unpruned trees on which damage occurs; (iv) dust application to chupon-pruned trees on which damage occurs. Each treatment is replicated six times.

Counts of capsids and damaged shoots have been made at fortnightly intervals throughout the year. Yield records have also been collected, but there have not yet been sufficient pods to justify using these data. Assessment of the effectiveness of the treatments at the end of this second year must, therefore, still be based on the capsid and damaged-shoot counts. The regular fortnightly removal of chupons has encouraged flushing and growth of lateral branches, and in plots which have received this treatment a closed canopy has already formed. In the unpruned plots some trees have formed a third jorquette but a closed canopy has not been attained.

From the counts it is clear that the capsid population has been higher in unpruned than in pruned plots, a difference which became more marked as the seasonal peak population was attained on surrounding cacao. As would be expected, the amount of damage on unpruned cacao has been greater than on pruned cacao, irrespective of the type of insecticidal treatment. During the course of the year an average of 18.2 capsids per 100 trees per visit were recorded on the unpruned compared with 5.4 on the pruned cacao. A statistical analysis of the data indicated a highly significant difference between the pruned and unpruned plots. Comparing the insecticidal treatments, 16.1 capsids per 100 trees per visit were found on the plots, both pruned and unpruned, which received the localised dust application, and 9.0 on the spray-painted plots. These observations are confirmed by the highly significant difference ($P=0.01$) indicated by analysis of the data on damaged shoots removed during the year. Eighteen damaged shoots per 100 trees were recorded per visit on unpruned compared with ten on pruned plots. This difference is even more marked than the figures suggest because a damaged shoot on an unpruned tree was usually the leading chupon, whereas that on a pruned tree was inevitably a fan. Damage to the former obviously has a far greater adverse effect on the tree. Comparison of the insecticidal treatments showed that an average of sixteen damaged shoots per 100 trees were recorded per visit on the dusted and twelve on the spray-painted plots.

It is thought that the reductions in capsid population and damage

which have followed removal of chupons are mainly due to the greater facility with which insecticidal treatment can be effected on the laterally branching trees; even though the spray-painting and dusting equipment is quite adequate to reach the vertical growth of the unpruned cacao, at its present stage. Other factors, such as relative canopy densities of the pruned and unpruned cacao and feeding preferences of the capsids, may be involved, but probably to a much lesser extent. The difference between the two insecticidal treatments is not so marked, although dust application to trees on which damage is found has proved less efficient than spray-painting all trees at regular intervals of four months. It is clear that this difference would have been more marked if the DDT aqueous emulsion had been applied at more frequent intervals.

A similar experiment, in which the four treatments are replicated seven times, was laid down at Akwadum on Upper-Amazon cacao at 12 ft. by 12 ft. spacing and nearly four years old. The treatments are in their second year. Although growth over the greater part of the area has been good, nowhere has a continuous canopy been formed.

Counts of capsids and damaged shoots have been made at fortnightly intervals. Statistical analysis of the data obtained so far has not shown significant differences between either the pruned and unpruned trees or the two insecticidal treatments. The absence of a difference in population on the pruned and unpruned trees may be explained by the fact that in spite of differential treatment there is very little difference in their habit at present, because of the comparatively little chupon growth on any of them. This may be due to the poor soil in the area and perhaps partly to the wide spacing encouraging lateral growth.

The above experiments will be continued for another year, by the end of which sufficient trees in both should have borne pods to give reasonably reliable data for an analysis on the effect of the treatments on yield.

POPULATION STUDIES (D. J. Taylor and P. F. Entwistle)

Reliable estimates of capsid populations in cacao are essential for assessing the importance of various factors on the bionomics of these insects, and to enable insecticidal control to be carried out with maximum effect and economy. Estimation from hand collections made at regular intervals has been practised at WACRI for several years (see previous Annual Reports); but these Routine Collections are time-consuming and susceptible to errors due to the 'human element', unless stringently supervised. Consequently, two supplementary methods are being tried: one involves the use of light-traps,

and the other counts of unhatched capsid eggs. Since an increase in the number of adults must always be preceded by an increase in the number of eggs, the latter method might provide a means of forecasting (and hence perhaps preventing) rises in capsid populations.

Light trapping (D. J. Taylor)

Monthly estimates have been made by this method. Two of the traps employed incorporate a vertically positioned 500-watt mercury-vapour discharge lamp above a funnel and killing-bottle arrangement to collect the attracted insects. They were placed 5 ft. above ground level in the cacao at sites about a mile apart in the WACRI experimental area. Records were also taken of capsids caught in a third trap designed by a colleague for the collection of ants. This utilised ordinary filament bulbs which are much less efficient than those emitting ultra-violet light.

Catches of *Sahlbergella singularis* Hagl. have been obtained regularly in both types of trap. Disregarding seasonal variation, the average nightly catch is of the order of two to three adults; occasionally as many as twenty-five were obtained. *Distantiella theobroma* does not appear to be attracted to light, since only five adults of this species have been found in the catches during the whole period. This was confirmed by releasing marked adults within 25 ft. of a trap; none was recaptured. *Helopeltis bergrothi* Reut. has been trapped only very occasionally, but *Bryocoropsis laticollis* Schum. adults were caught fairly frequently in one of the ultra-violet-emitting traps during the period August-November. However, as interest in these two pod-feeding species is limited, their response to artificial light has not been examined critically.

TABLE 10
Monthly population estimates

	Routine collections				Light-traps
	<i>Sahlbergella singularis</i>	<i>Sahlbergella singularis</i>	<i>Distantiella theobroma</i>	<i>Distantiella theobroma</i>	<i>S. singularis</i>
	Adults and nymphs on pods and shoots per 100 trees	Adults and nymphs per 100 seedlings	Adults and nymphs on pods and shoots per 100 trees	Adults and nymphs per 100 seedlings	log. (n+1) catch per light (mean of 3 traps)
April 1955	0.4	0.8	7.0	10.4	0.27
May "	0.1	0.2	7.9	9.5	0.29
June "	0.2	0.4	9.2	13.0	0.24
July "	0.2	0.5	11.6	13.9	0.15
Aug. "	5.0	0.8	13.8	13.6	0.31
Sept. "	11.3	3.2	28.0	15.1	0.33
Oct. "	7.7	3.5	22.9	14.6	0.44
Nov. "	7.7	4.8	22.6	17.4	0.32
Dec. "	9.7	6.2	21.3	16.5	0.61
Jan. 1956	4.6	4.9	30.1	19.7	0.45
Feb. "	6.4	6.4	18.7	15.6	0.55
March "	0.8	2.3	15.3	13.9	0.24

Table 10 shows monthly estimates of *S. singularis* and *D. theobroma* from the Routine Collections and of the former from the combined light-trap records. In order to obtain a more reliable guide to the abundance of the insects, data from the traps have been subjected to a log. $(n+1)$ transformation. The monthly variation indicated by all three traps was similar; though, as stated earlier, the level shown by the 'ordinary' trap was lower than that for the 'ultra-violet' ones.

It will be noted that the monthly variations of *S. singularis* shown by both methods agree closely. The light-traps are situated more or less in the centre of the Tafo area, from which the Routine Collections are made. Analysis of data for the last fifteen months shows a highly significant correlation ($r=+0.825$; $P=0.001$). By comparison with more intensive counts, previous workers have shown that the Routine Collections provide a reliable guide to gross fluctuations in population throughout the year. Consequently, it may be concluded that light-trapping is an effective method of sampling the *S. singularis* population.

Egg counts (P. F. Entwistle)

An experiment to investigate the possibilities of estimating capsid populations by egg counts was laid down, on two plots at Akwadum and one in the Square Mile, in January 1956. Immature cacao is being used. Samples of fan and chupon tissue are removed at fortnightly intervals and examined for unhatched eggs and a comparison made with direct bug counts on selected trees.

Obviously, the degree of correlation between unhatched-egg counts and counts of post-eclosion stages is a measure of the suitability of the sample sizes used. Results obtained by March seemed to indicate that too small a sample was being employed, a point well illustrated by amalgamating the results from two contiguous plots at Akwadum, when correlation became much closer. Consequently, the Akwadum plots are now being considered as a single unit whilst the Tafo plot has been extended so that a doubled sample can be taken.

As a preliminary to extension of this experiment to mature cacao, more information about the oviposition preferences of capsids was necessary. Little was definitely known, beyond the fact that they normally lay their eggs in fan, chupon or pod tissue damaged by previous feeding. An investigation was therefore commenced in February 1956, on two plots of closely spaced mature cacao, to elucidate the vertical distribution of eggs. Such knowledge has an obvious bearing on the sampling technique to be employed. Complete trees are felled, their height measured and the vegetative tissue divided vertically into 5 ft. lots, on each of which the number of eggs per 100 ft. of damaged tissue is assessed. In the plots sampled

so far the figure has increased, though not linearly, with height, as shown in Table 11.

TABLE 11
Vertical distribution of Capsid eggs

Height intervals	0-5'	5-10'	10-15'	15-20'	20-25'
Trees 15-20'	3.09	6.21	8.81	20.47	—
Trees 20-25'	0.00	2.34	9.90	12.70	18.30

The determinant factor in this distribution appears to be light, and eggs are not distributed in proportion to the vertical bulk distribution of available oviposition sites, nor to that of feeding sites. It is to be expected that egg distribution will vary with tree spacing and with the degree of shading, but the point has yet to be established.

Further incidental data on the type of growth preferred by capsids for oviposition has been obtained from the experiments on population estimation by egg counts and vertical distribution of eggs, the former giving information for immature cacao and the latter for mature bearing trees (Table 12). Whilst it is obvious that for cacao of both ages chupons are preferred, fans are not the negligible site they have been previously considered to be. In mature cacao they are more important than chupons, because of their numerical preponderance. Oviposition preferences have, in the past, been too greatly stressed; they are of less importance than the type of tissue available.

TABLE 12
Type of tissue preferred for oviposition

Type of cacao	Fan tissue %	Chupon tissue %	Eggs in fans %	Eggs in chupons %	Eggs in fan petioles %	Eggs in chupon petioles %
Immature	67.7	32.3	38.0	57.5	1.5	3.0
Mature	95.1	4.9	77.3	18.5	2.9	1.3

FUNGI ASSOCIATED WITH CAPSID LESIONS (G. Usher)

Introduction

Crowdy (*Ann. appl. Biol.*, **34**, p. 45, 1947) and Owen (*Ibid.*, **44**, p. 307, 1956) have already described the symptoms of infection by *Calonectria rigidiuscula* (Berk. & Br.) Sacc. on West African cacao, and partially elucidated its behaviour in the tree (see also previous Annual Reports). This fungus, which usually occurs in its imperfect (conidial) stage (*Fusarium decemcellulare* Brick), is primarily associated

with capsid lesions, and the frequency with which it invades them makes it one of the crop's major pathogens. In spite of improved prospects for controlling capsids by insecticides, and hence ultimately reducing infection by *C. rigidiuscula*, it is essential that more should be known about this fungus, particularly as regards its relation to the host. Very many mature cacao trees are already infected to a greater or less extent, though the majority will continue to bear satisfactorily so long as the fungus remains latent within the occluded capsid lesions. Unfortunately, under the influence of factors weakening the natural resistance of the tree, the pathogen is liable to grow out and cause chronic die-back or even death. Conditions conducive to severe effects are found in so-called capsid pockets.

Effect of environment on host and fungus reactions

A trial has been carried out, using four-month-old seedlings in baskets, to examine the effect of water and nutrient supply on growth with and without *C. rigidiuscula*, and on rate of invasion by this fungus. The treatments were 250 ml. of water weekly or 500 ml. daily, N, P and K in all combinations, and needle punctures in the stem inoculated with the fungus or uninoculated. After three weeks plants receiving daily watering had become significantly taller ($P=.05$) than those watered weekly. At the end of the experiment, which lasted ten weeks, plants inoculated with the fungus had significantly fewer leaves, and the lesions which developed round the punctures were significantly longer. Lesions in weekly watered plants were larger (though not quite significantly so) than in daily watered ones, but the manurial treatments did not appear to have affected lesion size. In all instances but one, *C. rigidiuscula* was recovered in culture from inoculated lesions, sometimes along with *Botryodiplodia theobromae* Pat.; uninoculated punctures never yielded the former, but usually the latter.

Dissemination

The possibility of capsids carrying spores of *C. rigidiuscula* has been studied. For this purpose, 216 adults of *Sahlbergella singularis* and *Distantiella theobroma* were collected in the field and enclosed for half an hour on Petri dishes of cassava-dextrose agar. These were then kept in full daylight at room temperature for forty-eight hours, after which the fungi which had developed were identified as far as possible. *C. rigidiuscula* was isolated from 11 per cent. of the insects, other *Fusarium* spp. from 23 per cent., *B. theobromae* from 9 per cent. and other fungi from 98 per cent. A large proportion of these other fungi were *Aspergillus*, *Penicillium* and *Cephalosporium* spp. In a further experiment, seventy-three capsids were dissected into legs, body and

mouthparts, which were plated out separately. *C. rigidiuscula* was isolated only from bodies and legs, which suggests that any transfer of the fungus by the capsids is purely fortuitous, there being no biological relationship between the two organisms. It is therefore possible that other insects, such as ants, may be equally or more important than the capsids themselves in disseminating the fungus. This is being tested. An attempt is being made to ascertain the relative abundance of *C. rigidiuscula* spores in the air of cacao plantations, and on the young branches of cacao trees showing no obvious capsid damage. Petri dishes containing cassava-dextrose agar have been exposed in the cacao on the Old Station and the organisms collected allowed to grow for two days; out of 200 such dishes none has shown *C. rigidiuscula*. Pieces of young branch, 5 cm. long and 6–10 mm. in diameter, have been collected, each washed in 1 ml. of sterile distilled water, and the washings plated on cassava-dextrose agar; of 128 pieces examined eight have yielded the fungus.

It would seem from these preliminary results that spores of *C. rigidiuscula* are unlikely to be air-borne, but are carried to some extent by capsids and possibly other insects, and perhaps by rain-water. This last possibility is being further investigated. The period during which capsid punctures remain susceptible to invasion is being studied, since it has a bearing on the relative importance of different agents of dissemination.

Cultural studies

Experiments on the growth of *C. rigidiuscula* on cassava-dextrose agar showed a positive correlation ($P=.05$) between the final diameter of the colony and its dry weight after ten days, but there was no correlation between daily increase in diameter and daily increase in dry weight. The comparison of growth on different media by measurement of the diameter of the colonies is not valid. In 20 ml. of a liquid medium made of cassava and dextrose, growth (as measured by dry weight) followed the usual curve, the staling effect becoming obvious after ten days.

When colonies on cassava-dextrose agar were subjected to continuous illumination or darkness the usual colour zonation did not appear, light being responsible for development of the typical Corinthian purple pigment. Illumination had no effect on size or septation of macrospores, nor on size of microspores. By culturing the fungus in various modified forms of Richard's solution or on a solid medium made by addition to it of agar-agar, certain information about its nutrient requirements has been obtained. The daily increase of growth on solid medium and final dry weight of mycelium after ten days' growth in liquid medium were not greatly affected by

changes in C/N ratio, brought about by altering the concentrations of sucrose or KNO_3 . At sub-normal nitrogen level, growth was better on a medium with twice the normal concentration of sucrose. Using four different nitrogen sources, it was shown that growth is good with KNO_3 and amino-acetic acid but greatly reduced with $(\text{NH}_4)_2\text{SO}_4$, NH_4NO_3 being intermediate.

On solid medium made from ordinary Richard's solution, microspores were generally produced in three days and macrospores in about a week. Using sucrose as a carbon source, microspores were produced on all media, except where $(\text{NH}_4)_2\text{SO}_4$ was the nitrogen source. Macrospores were not produced in the absence of N or P, nor if $(\text{NH}_4)_2\text{SO}_4$ was used as the nitrogen source. When glucose was used as the carbon source very few macrospores were produced, and then only if the complete medium or one lacking only MgSO_4 was used. A few microspores were produced on all the glucose-containing media. Hardly any microspores and no macrospores were produced when no carbon source was present.

It has been shown that *C. rigidiuscula*, when cultured in Richard's solution, produces a thermostable ethanol-soluble toxin which will produce wilt in excised tomato seedlings.

The method of development of both macrospores and microspores has been elucidated; the latter develop basipetally, as do the septa of the former. These two types of spores were subjected to different temperatures for various periods to determine their upper thermal death point. The germination rate in distilled water fell from 9 per cent. after five minutes' heating at 45°C . to nil after twenty-five minutes at 60°C .

EXPERIMENTS ON ESTABLISHMENT AND MAINTENANCE (R. J. Benstead)

ESTABLISHMENT TRIALS

Trees in the First Establishment Trial that were planted out as basket seedlings have again shown better performance than those established otherwise, though severe capsid damage has masked treatment differences. The yield of pods from the Second Establishment Trial is as yet too small to use as a criterion of establishment, averaging only 0.12 pods per tree.

There is visual evidence that the pruning treatment has accelerated formation of a canopy, but this is so low as to make access to the trees difficult.

SPACING TRIALS

Data from the Amelonado Spacing Trial are inconclusive and do

not bear any relation to those for the previous year. Table 13 illustrates the inconsistency of treatment performances.

TABLE 13
Mean plot yields in pods per plot of 400 square yards

Spacing	15' × 15'	12' × 12'	10' × 10'	7½' × 7½'	7½' × 6'	6' × 6'	5' × 5'	4' × 4'
1954/55	145.4	206.9	96.0	74.4	141.7	100.9	93.0	108.4
1955/56	108.6	128.6	142.3	187.0	141.1	155.1	185.3	110.5

Growth in the Upper-Amazon Spacing and Pruning Trial has been extremely vigorous, and at just under seven years from planting the canopy at the widest spacing on both the pruned and unpruned plots has integrated. Chupon growth on the pruned trees has been very prolific and vigorous; therefore the frequency of their removal has been changed from monthly to fortnightly, to prevent them becoming too woody. Data for the various treatments over the last two seasons indicate that yield per acre and pods per tree are inversely related to density. The apparent difference in yield between unpruned and pruned plots is not statistically significant (Table 14).

TABLE 14
Yields from the Upper-Amazon Spacing and Pruning Trial for the 1954-55 and 1955-56 crops

Spacing	8' × 8'		10' × 10'		12' × 12'	
	1954-55	1955-56	1954-55	1955-56	1954-55	1955-56
<i>Unpruned plots</i>						
Pods per tree ..	4.92	6.83	6.56	12.09	9.09	18.42
Dry cocoa per acre (lb.) ..	298.7	387.2	255.4	439.3	245.1	463.6
<i>Pruned plots</i>						
Pods per tree ..	4.71	6.65	6.76	11.17	9.20	17.69
Dry cocoa per acre (lb.) ..	286.0	376.7	263.2	406.0	248.1	445.2

OTHER TRIALS

The proposed experiment to compare the yields of seedlings and rooted cuttings (*Ann. Rep. WACRI*, 1954-55, p. 71) has been abandoned. Shortage of material had precluded laying out further replicates, and in the one already planted serious loss of cuttings had occurred. The experiment designed to compare rooted cuttings with chupons removed or allowed to grow (*loc. cit.*, p. 73) has been also abandoned, due to the death of many plants and poor growth of the survivors. Too dense a shade may have been responsible, and it is clear that more needs to be known about the establishment of cuttings under local conditions. Good plants are being removed for other purposes.

The experiment on the effect of soil type on pod development and yield, and that on methods of crop forecasting (*loc. cit.*, pp. 71-73) are being continued, but in the absence of an officer with sufficient statistical knowledge it has not been possible to analyse the data obtained.

SOIL FERTILITY, SHADE, AND MANURIAL REQUIREMENTS

EFFECT OF MAJOR NUTRIENTS ON CACAO (S. N. Adams)

Trials on young Amelonado

The nine NPK trials on seedlings planted in 1953 (*Ann. Rep. WACRI*, 1953-54, p. 17; *Ibid.*, 1954-55, p. 73) were continued. Now that many plants have jorquetted, height is no longer a satisfactory criterion of performance, so main-stem diameters are being measured instead. On this basis, significant responses to superphosphate have been recorded at Poanu and Juaso. The response at Poanu was observed in 1954-55, but that at Juaso has developed during the course of this season; both are small and do not bring seedling performance up to that observed on the outstandingly vigorous trial at Goaso.

TABLE 15

Seedling diameters at Poanu 34 months after planting

Treatment ..	O	N	P	K	NP	NK	PK	NPK
Diameter (cm.) ..	2.06	1.49	2.39	1.90	2.29	1.49	2.25	2.14

A large and highly significant depression due to sulphate of ammonia has been observed at Poanu (Table 15). This is shown only in the N and NK treatments and has been completely offset by superphosphate. Such an effect may tie up with the results of leaf analysis on trials at Tafo and Bunso, where sulphate of ammonia was shown to have significantly reduced phosphate uptake. Moreover, a test on one of the Tafo experiments showed that sulphate of ammonia had reduced the soil pH by one unit. As repeated dressings of sulphate of ammonia reduced soil pH and uptake of phosphorus, another form of nitrogenous fertilizer might be more suited to cacao. The lack of response in these trials should not, therefore, lead to the conclusion that the seedlings do not require fertilizer nitrogen.

To see if excessive shade is responsible for the lack of large responses to fertilizer, three out of the six blocks on each of the trials

at Tafo (2 sites) and Bunso were gradually denuded of shade during the 1955 rainy season. Both visual observation and measurements of girth suggested that the initial effect of shade reduction was to stimulate growth; but as replication is inadequate, this point could not be proved statistically. The unshaded plants survived the dry season without any obvious ill-effects due to drought, but by the end of April 1956 they were beginning to look unhealthy, and leaf scorch appeared on some. No effects of fertilizer were recorded in either the shaded or unshaded sections of the trials.

When a mixed forest shade is removed from cacao seedlings in this way, numerous factors come into play. Due to increased light intensity, vigorous growth of ground vegetation takes place on the unshaded plots. An attempt has been made to exclude grass by farming a cover of cocoyams, but at Bunso the latter failed to establish, so that grass has become dominant and the unshaded cacao looks more unhealthy than that at Tafo. It is not possible to say from these experiments to what extent this invasion of grass is responsible for the present unthrifty appearance of the seedlings. Those without shade are more subject to thrips attack and the leading chupon is frequently destroyed by caterpillars of the moth *Earias* sp. This differential attack by insects at differing light intensities is another factor to be taken into account when considering the role of shade in cacao culture.

It must be emphasised that the three experiments on which shade has been removed were originally laid down as fertilizer trials, and not designed for studying the effect of shade. At the moment, numerous large dead forest trees stand in the plots and considerable damage will be caused to the cacao when they fall. For this reason, the trials are not suitable for long-term investigations on the shade-fertilizer interaction.

Trials on Upper-Amazon Cacao

Work has been continued on the $2 \times 2 \times 2$ factorial NPK trials at Asokore, Jumapo, Bunso and Anyinam. The Bunso plot alone has produced a substantial yield and there a 19 per cent. response to superphosphate has been observed. This only just attains significance ($P=0.05$) and great importance should not, therefore, be attached to it.

The plots at Asokore and Bunso are adjacent to roads or footpaths and the trees at the edges are subject to a certain amount of exposure. It was noticed that these semi-exposed trees were more vigorous than those in the interior of the plots, and in the 1954-55 harvest they produced a much larger yield (Table 16). A simple explanation of this edge effect would be that the plots as a whole were over-shaded,

so that only when trees received a higher light intensity was good performance obtained. If this was so, no large fertilizer responses could be expected. Shade reduction is now proceeding on these Upper-Amazon plots and the trials are being continued.

TABLE 16

Effect of exposure on yield of 5-year-old Upper-Amazon seedlings

Site		No. of trees	Yield in pods	Pods per tree
Asokore				
Edge row ..	..	41	394	9.61
2nd row from road ..	..	40	147	3.68
Rest of plot ..	..	813	597	0.73
Bunso				
Edge row ..	..	164	1,350	8.23
Rest of plot ..	..	1,600	6,387	3.99

Trials on mature peasant Cacao

The Department of Agriculture has completed yield recording for the 1955-56 harvest in the fifteen farms selected for future manurial trials. Individual-tree yield recording on the Unit Farm at Wiawso was started this season.

EFFECT OF MAJOR NUTRIENTS FROM DIFFERENT SOURCES (S. N. Adams)

Routine work and harvesting have been carried out on the 'types-of-nitrogen' trial at Nankese and the 'types-of-phosphate' trial at Kabu Hill. Neither plot has yet produced a full crop, and no responses to fertilizer have been measured. Shade reduction is being carried out at the two sites and the experiments will be continued.

MINOR-ELEMENT DEFICIENCIES (A. D. McKelvie)

Fairly widespread iron and zinc deficiency symptoms have been observed on the Station and a plot with suspected magnesium deficiency has been noticed. Because it was observed by Greenwood and Hayfron (*Emp. J. exp. Agric.*, **19**, p. 73, 1951) that sickle-leaf disease, caused by zinc deficiency, occurred commonly near rotting tree stumps and pod husks, rotted wood was applied as a heavy mulch around the bases of Upper-Amazon T12 trees. Although this was done over 16 months ago, no zinc deficiency has yet been seen and weekly counts of flowers and pods reveal no differences between treated and control trees. A survey of the Introductions Area revealed a high incidence of sickle-leaf disease and a marked reduction in the yield of affected trees in recent years. No attempt to cure this condition has been made, due to lack of staff; but it is apparently

quite serious, at least in certain parts of the Station, and requires attention. Soil and leaf samples from affected areas were sent to the Colonial Products Laboratory for estimation of trace elements.

EFFECT OF DAY LENGTH AND FERTILIZER TREATMENT ON GROWTH OF CACAO SEEDLINGS (A. D. McKelvie)

This experiment was described in *Ann. Rep. WACRI*, 1954-55 (p. 92), some observations being made on growth and damage by insects. The experiment has ended and mean heights of the seedlings after six months are recorded in Table 17. Growth was best under natural day length (06.00-18.00) and worst under a day length of four hours, but it was better to have the four-hour period in the morning than in the afternoon. This is almost certainly a temperature effect. Phosphate gave a significant response under the eight- and 12-hour treatments.

TABLE 17

Seedling heights (cm.) for various light and fertilizer treatments

<i>Hours of exposure</i>	08.00-12.00	08.00-16.00	06.00-18.00	12.00-16.00	<i>Treatment means</i>
<i>Treatment</i>					
Nitrogen ..	16.20	24.16	33.95	10.00	21.08
Phosphate ..	15.20	26.45	35.20	11.16	22.00
Potash ..	15.70	22.16	30.91	7.79	19.14
Control ..	16.33	24.29	29.16	9.12	19.72
<i>Treatment means</i> ..	15.86	24.26	32.30	9.52	20.49

EFFECT OF ORGANIC AND INORGANIC MULCHES IN RELATION TO SHADE AND FERTILIZER TREATMENT (A. D. McKelvie)

The layout of this experiment was discussed in *Ann. Rep. WACRI*, 1954-55 (p. 92). Three types of shade treatment were used: (i) no shade; (ii) artificial shade of cut palm fronds; (iii) sparse, living top-shade of tree cassava and *Gliricidia*. The experiment was carried on for nine months and then terminated, because it had become impossible to keep the shade treatments as specified. The mean heights of plants in the various treatments at the end of the experiment are given in Table 18. Artificial shade was better than either no shade or natural shade, and organic mulch with or without nitrogen was superior to any of the other soil treatments. Without shade, all soil treatments were ineffective. Under artificial shade,

organic mulch, nitrogen, and the two together were effective, but under living shade only organic mulch without added nitrogen gave satisfactory results.

TABLE 18

Seedling heights (cm.) for various mulch and shade treatments

Soil treatment				Artificial shade	No shade	Living shade	Treatment mean
Sand	..	..	..	42.57	27.76	31.86	34.06
Organic mulch	..	..	..	57.27	39.87	41.34	46.16
Nitrogen (N)	..	..	..	56.65	32.69	33.30	40.88
Sand+N	..	..	..	47.10	28.40	31.91	35.80
Organic mulch+N	..	..	..	66.84	29.19	33.78	43.27
Control	..	..	..	42.90	39.35	35.28	39.18
Treatment mean	..	..	..	52.22	32.88	34.58	39.89

ROOT STUDIES

(A. D. McKelvie)

GROWTH OF CACAO SEEDLINGS ON TWO CONTRASTING SOILS

An experiment has been laid down to study the growth of seedlings—especially as regards their root systems—from planting until they come into bearing. Two contrasting soil types have been selected—the Koforidua series which is a free-draining soil considered suitable for cacao, and the Akwadum series which is a heavy clay soil in valley bottoms, considered unsuitable. Shade conditions were made as uniform as possible, and seed at-stake was planted in June 1955. There are eight replications on each soil, and four plants from each replication are being dug up for analysis each month.

In the early months there was little to choose between root growth on the two sites, but while the plants on the Koforidua series suffered little check in the dry season those on the Akwadum series were badly affected and many died. The water content of the former soil (at a depth of 6 in.) dropped to 9 per cent. and that of the latter to 5 per cent. Table 19 shows the difference in growth of the seedlings on the two soils after ten months in the field. The low mean leaf area on the Akwadum series is due to considerable defoliation in the dry season.

TABLE 19
Growth on two soil types

Soil type	Mean height (cm.)*	Mean girth at ground level (cm.)	Mean leaf area (cm. ²)	Mean total dry wt. (g.)	Mean root dry wt. (g.)	Mean length of tap-root (cm.)	Deaths %
Koforidua Series	45.0	0.7	1628.3	8.6	1.8	19.2	15.6
Akwadum Series	30.2	0.5	87.5	2.0	0.6	18.2	63.6

*All means based on 32 plants.

GROWTH OF CACAO SEEDLINGS IN ASSOCIATION WITH OTHER PLANTS

This series of experiments (*Ann. Rep. WACRI*, 1954-55, p. 76) has been continued, and Table 20 shows the size of cacao seedlings after being grown for four months in pots with several different species. It is clear that grass is the worst competitor and that *Ceiba pentandra* and *Commelina* sp. also have a depressing effect. How much of this is due to competition for root room will be investigated when the plants are dug up and analysed.

TABLE 20
Growth in competition with other plants

Competitor	Height (cm.)*	Girth (cm.)*	No. of leaves*
<i>Ceiba pentandra</i> (seedlings)	22.9	0.8	10.0
Cocoyams ..	29.9	0.7	17.3
<i>Commelina</i> sp. ..	26.0	0.6	6.9
Grass ..	19.8	0.7	9.0
Control ..	30.0	0.8	12.7

* Means for 12 plants.

VEGETATIVE PROPAGATION

(A. D. McKelvie)

SIMPLIFIED TECHNIQUES

As reported in *Ann. Rep. WACRI*, 1954-55 p. 76, experiments have been going on in an endeavour to simplify the production of rooted cacao cuttings. In the earlier attempts, two-leaf cuttings were inserted in a bed of well moistened soil and covered with polythene sheet, laid directly over the leaves and weighted at the edges. The

technique has been greatly modified during the year and has now reached a stage where it can be recommended as an efficient and inexpensive method of vegetative propagation.

Initially, some difficulty was experienced in successfully hardening the cuttings, as roots produced in the soil were thick and tended to break on transplanting into baskets. Hardening *in situ* was then tried, by lifting the polythene sheet for gradually increasing periods of time until the process was complete. This was not found satisfactory and was abandoned in favour of a modification of the former practice, in which cuttings were placed in paper pots filled with soil and then inserted into the bed. In some instances a central core of rooting medium (50:50 sand and composted oil-palm fibre) was used in the paper pot. It was hoped that the method would prevent roots from being damaged on transplanting into baskets, but they grew out through the pots and defeated this aim. Finally, it was decided to root and harden the cutting in one basket, and it is thus that fuller exploitation of the potentialities of the polythene-sheet technique has been achieved. Of the variations tried, the following is the one finally adopted and which is recommended as giving the best results.

Two-leaf cuttings are taken early in the morning, given the usual quick dip in β -indole butyric acid and inserted in a core of rooting medium surrounded by soil in a basket. Usually about 30 such baskets are placed together on the ground under slatted bamboo or natural forest shade and covered, after ample watering, with a sheet of polythene 3/1000 in. thick (no other thickness has been tried as this appears very satisfactory). The polythene is laid directly over the leaves and weighted down around the baskets. Every three days the sheet is removed and a light sprinkling of water given. As yet, no critical experiments have been done on the amount of watering required but the present routine appears satisfactory. After four weeks the cuttings have rooted and hardening can begin. It should not be further delayed or roots grow too far out of the baskets and a check to growth occurs when the sheet is removed. This is done by stages: during the first week the cuttings are uncovered from 6.30 a.m. to 10 a.m., and during the second and third weeks until 11 a.m. and 12 noon successively. They are then stored under shade preparatory to being planted in the field. Sometimes a cutting dies at this stage and is found to have produced no roots, in spite of having given no appearance of failure during hardening. As this loss is only of the order of 1-2 per cent. it is negligible.

Over 90 per cent. success may be expected; out of 30 cuttings rooted in a batch it is usual to get about 28 successfully hardened. Table 21 gives rooting and hardening data for the various methods used.

TABLE 21

Comparison of rooting and hardening methods

<i>Method of rooting</i>	<i>Method of hardening</i>	<i>% rooting</i>	<i>% hardening after rooting</i>
1. Polythene sheet over bed of soil	Transplanted into baskets and placed in hardening bin	68	95
2. Polythene sheet over bed of soil	<i>In situ</i>	59	92
3. Polythene sheet over bed of soil and cuttings in paper pots	Transplanted into baskets and placed in hardening bin	51	99
4. Cuttings inserted in soil in baskets and covered with polythene sheet	Hardened in the same basket under polythene sheet	80	100
5. As 4 but a central core of rooting medium added	Hardened in the same basket under polythene sheet	92	100

Both material and labour are saved by this technique: no expensive bins are necessary and very little rooting medium (which is laborious to prepare and hard to obtain in large amounts) is required; repotting after rooting is eliminated, while less watering is required than with conventional methods, an important advantage where water supply is difficult. Polythene sheeting used for more than a year is still untorn. Certain flour and sugar manufacturers are enclosing their products in polythene bags and these may prove a suitable source for small-scale propagation.

PLANT BREEDING AND SELECTION

(A. D. McKelvie)

Although there were no Plant Breeders at the Institute during the year under review, this work has been continued and expanded according to schedule. Consignments (totalling 124 plants) of *Herrania* and *Theobroma* species which were collected on the Anglo-Colombian Expedition have arrived from Kew. These are now ready to be planted out and an area of land has been prepared. They include: *Herrania nitida* (Poeppig.) R. E. Schultes; *H. camargoana* R. E. Schultes; *H. cuatrecasana* Garcia-Barriga; *H. umbratica* R. E. Schultes; *Theobroma cacao* L. (several varieties); *T. bicolor* Humb. and Bonpl., and *T. calodesmis* Diels.

PROGENY AND INTRODUCTIONS TRIALS AT TAFO

Yield recording in all these trials has been continued. They now cover 45 acres and contain 22,000 trees, each of which has to be individually harvested weekly. Every pod is classified according to whether it is healthy, rodent-damaged or infected by black-pod disease, and whether borne on the trunk or branches. Individual weights of beans are also recorded. As the new trials come into bearing this type of recording will be extended to them.

Yields from the Introductions have again fallen this season, for the third year in succession, and it must now be considered that they are past their peak after eleven years in this particular area. The yield of the Amelonado controls has also diminished. This decline may be due to senescence, soil exhaustion or alterations in shade conditions. The 1st Clonal Trial has maintained its yield but that of the 2nd Clonal Trial has fallen slightly. The performance of the best selections is shown in Table 22.

TABLE 22
Yields from the best selections: 1955-56

<i>Area</i>		<i>Selection</i>	<i>Age from planting out (years)</i>	<i>Yield in lb. dry cocoa/acre (computed)</i>
2nd PTA	..	E1	14	867
10' x 10' ..	..	TF1	14	635
		A72	14	599
1st Clonal	..	ACU85	9	841
10' x 10' ..	..	A46	9	743
		K5	9	724
2nd Clonal	..	R15	7.5	974
8' x 8' ..	..	B1	7.5	776
		W41	7.5	689
Introductions	..	T60	11	1,148
14' x 14' ..	..	T79	11	889
		T72	11	887
		T76	11	768

The 8th P.T.A. has yielded well in its fourth year in the field and the data are given in Table 23. This trial (planted in 1952) is the first to incorporate the new hybrid selections and results are awaited with great interest. Bean-size figures are very variable on such young trees but it appears that the hybrids have larger beans than their Upper-Amazon parents. Small samples were fermented and are being submitted to the chocolate tasting panel for flavour assessment. It will be several years before selections can be made from this trial for distribution to 'Nucleus Plots' on Department of Agriculture stations.

TABLE 23
Yields from parents and best hybrids—4th year

<i>Selection</i>	<i>Trees in bearing</i> %	<i>Pods per tree (all trees)</i>	<i>Wet wt. of beans per tree (g.)</i>	<i>Wet wt. of beans per pod (g.)</i>
Amelonado (WA2) ..	2	0.04	3.3	80.0
Local hybrid (WB2) ..	19	0.27	31.8	127.5
Upper Amazon (WE4)	61	2.68	296.0	111.0
Amelonado × Upper Amazon (WAE5) ..	77	2.80	347.7	125.2
Local hybrid × Upper Amazon (WBE3) ..	68	3.09	392.5	127.3

The 9th P.T.A. (planted in 1954) is coming into bearing and girth measurements suggest great vigour amongst the crosses.

The 3rd Clonal Trial, to test Upper-Amazon selections as cuttings, was not planted in 1955 but will go into the field in May 1956. The area is staked and ready for planting when the rains come. The plots are being arranged to offset self-incompatibility in the clones.

GROWTH AND YIELD TRIALS AT OTHER SITES

Girth measurement has been continued on the nine Series I Variety Trials (*Ann. Rep. IWACRI*, 1953-54, p. 27). Trees are in bearing on the one at Bunso and harvesting is expected to begin this year on the others. Table 24 shows the variability in growth of the same selections, as shown by girth measurements in 1955, on different sites all planted up at the same time.

TABLE 24
Average girth per tree (cm.)

<i>Site Selection</i>	<i>Oyoko</i>	<i>Juaso</i>	<i>Kwadaso</i>	<i>Poano</i>	<i>Bechem</i>	<i>Goaso</i>	<i>Biene</i>	<i>Akaa</i>
T60 ..	7.4	4.8	5.3	6.7	6.9	7.0	—	5.6
T17 ..	6.9	—	5.8	—	—	6.6	—	5.8
S72 ..	5.8	4.8	—	—	5.7	—	4.9	5.2
TF1 ..	5.3	4.6	4.7	4.8	5.3	5.2	4.6	4.6
T12 ..	—	5.4	—	—	—	—	5.9	—
T85 ..	—	5.6	5.0	7.3	7.0	6.7	6.0	5.1
N38 ..	—	—	5.3	5.6	—	5.7	—	—
T79 ..	—	—	—	3.7	6.7	—	5.9	—

Of the eight Series II Trials originally planned for 1956 only four will be planted—at Pankese, Asikuma, Apedwa and Oyoko; for several reasons there were not sufficient hand-pollinated pods, so the proposed trials at Fumso (Brofeyedru), Buaku, Wamfie and Foso have been postponed. Hand-pollinations are going ahead rapidly to

ensure adequate supplies of seed for these remaining Series II Trials in the Gold Coast, for two one-acre trials (to be planted in June 1956) at I.N.A. farm and Ibule in Western Nigeria, and for up to six trials in Western and Eastern Nigeria in 1957.

NATURAL POLLINATION

Data continue to accumulate from the five-acre block of incompatible E1 cacao at Bunso Plantations, and it is now possible to see trends of setting in the line of the prevailing wind. A new albino plot is coming into bearing but, judging from the evidence of the previous one, is unlikely to yield much information about the mechanics of pollination. Further work on the subject is described in a later section of this report (p. 79).

INCOMPATIBILITY

Work was continued, and is now almost complete, on the genetical system governing incompatibility in certain introduced cacao populations. Further publications dealing with it are in the press.

POLYPLOIDS

A paper on the polyploids induced in *T. cacao* and related species is in the press and will be published shortly. These plants continue to grow well and may be expected to produce some flowers in 1956. Further suspected polyploids were planted out in 1955 but many of them still await examination to assess the degree of polyploidy present.

PHYSIOLOGY OF FRUITING

(A. D. McKelvie)

FACTORS INFLUENCING YIELD

The first year's recording has been completed on ninety-six trees of selection ACU 85 in the 1st Clonal Trial, in an attempt to find what factors most influence yield. Weekly records have been kept of flowers, healthy and wilted pods, and flushing. It has been shown, amongst other things, that yield is positively correlated with flower setting and number of leaves per tree, but bears no obvious relationship to the percentage of cherelle wilt on any given tree. The standard-error of the yield of a single tree of this selection is around 70 per cent.

CHERELLE WILT

Importance and possible causes

Although cherelle wilt may account for the loss of 70 to 90 per cent.

of all pods on a tree, this obviously does not imply that by completely preventing it yields would be correspondingly increased. If all the pods formed reached maturity then they would probably be minute and contain very little cocoa. The loss of nutrients from a tree through pods wilting is probably unimportant when it is considered that one mature pod contains about as much mineral matter as thirty 5 cm. long, the average length at which they wilt during the season. In a tree ripening thirty pods and having 80 per cent. wilt there would be mineral matter lost sufficient only for an extra four mature pods. This assumes that all food materials in a wilting cherelle are lost; in fact, some substances may be taken back into the tree, and this is being investigated at present.

Thus, it would seem that cherelle wilt is of little importance if it is true that a tree can only produce as many ripe pods as its reserves allow and that wilt is caused entirely by lack of food materials. Evidence has, however, accumulated during the past year to throw doubt upon this assumption and to suggest that factors other than competition for nutrients are operating.

In most experiments on cacao in which increased yields have been obtained by some cultural method, this has not come about by a reduction in the percentage of pods wilting, but by an increase in flowering coupled with an unchanged percentage of flowers set and pods wilted. On the other hand, a very small increase in percentage wilting can mean quite a big difference in the number of pods harvested. If a tree is stripped of its developing crop in an attempt to give hand-pollinated pods a better chance of coming to maturity, there is still a high percentage of wilt. It is not usually as high as for an untreated tree but this may be because most hand pollinations are done on the trunk, where pods are less susceptible to wilt than on the branches.

As reported in *Ann. Rep. WACRI*, 1954-55 (p. 89) cherelle wilt is most liable to occur at two distinct stages, both relatively early in the development of the pod. This has been confirmed for further cacao selections, and a paper on the subject is now in the press. Although wilt is generally highest between April and June, the calls on a tree's food reserves are quite small at that time compared with the enormous demands made by the maturing crop from August onwards—which are nevertheless successfully met. It seems strange that a tree cannot support from April to June a small fraction of the crop it can carry from August onwards. One of the questions which it is hoped to elucidate with the aid of radioactive isotopes is the rate of uptake and storage of mineral substances from the soil throughout the year. Such knowledge might suggest a reason for seasonal wilting.

Other possible causes of cherelle wilt are the production in the

tree, at certain times, of growth-inhibiting substances; or, conversely, an inadequate supply of growth promoters (plant hormones). From preliminary work using the growth-substance bio-assay technique of Archibald (*Ibid.*, 1953-54, p. 22) with cacao embryos, it appears that there may be growth-inhibiting substances present in large pods which are not present in small ones. Although proof is still needed, it is possible that such inhibitors may diffuse from the former to the latter, causing them to wilt. This would be analogous with other crops, but is still only a working hypothesis for cacao.

Hormone-application trials

In an attempt to find out if wilt is caused by a shortage of hormones, cherelles at their most susceptible stages of development (see above) were sprayed with two growth substances during the 1954-55 season, without obvious result (*Ann. Rep. WACRI*, 1954-55, p. 90). However, it was decided to make further trials, studying the effect of the sprays more closely. A randomised-block experiment on six cacao selections in the 1st Clonal Trial, using 0, 25, 100 and 250 p.p.m. of α -naphthalene acetic acid (NAA), was begun in May, and further applications of this substance were made in June and August. All wilted pods were collected weekly and measured, to see if there was any indication of a relationship between pod size and influence of NAA. No such effect was noticed at 25 and 100 p.p.m., and at 250 p.p.m. there was a marked increase of wilt amongst pods of all sizes in the week after spraying, coupled with yellowing of many older leaves. The 250 p.p.m. level was obviously toxic, while 25 and 100 p.p.m. had no observable effect, even on pods at a stage of development when very susceptible to wilt. In another experiment, 100 pods (between 4 and 7 cm. long) were selected and measured. Thirty-three were sprayed with 100 p.p.m. NAA, 33 had lanolin containing 100 p.p.m. NAA applied to the stalk, and 34 were treated on the stalk with lanolin alone. These pods were measured every three days for 12 days after applying the treatments, but there was no significant change in relative growth rate, and the percentage wilt was similar for each treatment. Further work of this nature has been suspended until it can be found whether growth substances applied externally to pods can penetrate them. It is hoped this coming year to study the movement of growth substances containing radioactive carbon applied to pods and leaves.

Effect of flushing on Cherelle Wilt

It was found (*loc. cit.*) that prevention of flushing produced a reduction in cherelle wilt for a few weeks. This suggested that flushing may entail competition with the developing pods for

nutrients or growth substances. To investigate the effect of flush removal on cherelle wilt more fully and to assess the influence of this treatment on yield, a randomised-block experiment was carried out on six selections in the 2nd Clonal Trial. All developing leaf buds were removed from March to September inclusive. The immediate effect was to reduce wilting during April, when control trees lost most of their developing crop. As a result of these early pods escaping wilt there was an early crop, the peak for treated trees being in August while that for the controls was not until the end of September. Total yields were 219 and 260 pods respectively, although by September there were $2\frac{1}{2}$ times as many leaves on the control trees. This suggested that lack of carbohydrates and other elaborated food reserves from the leaves was not affecting wilt, which was in fact reduced by the treatment (Table 25); but wet weight of beans per pod was 171.0 g. in control trees as against 158.3 g. in treated ones, indicating that pod size was being reduced.

TABLE 25
Effect of flush prevention

			<i>Pods harvested</i>	<i>Pods wilted</i>	<i>Flowers formed</i>	<i>Wilt %</i>
Flush prevented	..	..	219	619	25,492	74
Controls	..	..	260	1,269	35,660	83

While it is obvious that preventing flushing for seven months must have a bad effect on the trees, the ultimate aim is to control it for a short period while the developing crop is most susceptible to wilt. Simpler and less drastic methods of effecting this are being tried.

It was observed that maleic hydrazide had a depressing effect on the flushing of young cacao seedlings. This was therefore tested on trees in the field at a concentration of 0.1 per cent. in an aqueous spray. Weekly records were taken of the degree of flushing, but no treatment differences were noted. It is likely that, to be effective, spraying should be done at a critical time before a flush is due to open; but it has not yet been found possible to investigate this.

Effect of ringing the pod stalk on Cherelle Wilt

Ninety Amelonado pods were measured. Thirty of these were left as controls, thirty were completely ring-barked on the stalk, and on the remainder only half the circumference of the bark was removed. Microscopic examination showed that phloem only was removed, the xylem remaining intact. The treated stalks were smeared with wax to prevent water loss through the exposed surfaces.

Where the stalks were completely ringed, growth stopped very rapidly and all the pods had wilted after twelve days. Those on the half-ringed stalks slowed down slightly in growth compared with the controls, but only one had wilted after eleven days. No control pods wilted. Even with the smallest pods, removal of phloem caused decreased growth, indicating that there is always a demand for nutrients carried through this tissue.

Effect of male parent on Cherelle Wilt

To test whether the male parent of a cross has any influence on cherelle wilt, hand pollinations were carried out on Amelonado trees using two different pollen sources. All sets were examined weekly and size at wilting noted. The conclusion was reached that the male parent has no influence on the susceptibility of a pod to wilt.

EFFECT OF NAPHTHALENE-ACETIC ACID (NAA) ON RIPENING

Pods which had almost reached final size but had not begun to ripen were sprayed with 50 p.p.m. NAA, to see if there was any acceleration of ripening. Visual assessments of the degree of ripening were made every three days, but there was no difference between treated pods and controls sprayed with water. This work is being continued with other growth substances.

EFFECT OF OVER-BEARING IN THE EARLY YEARS ON SUBSEQUENT YIELD

Evidence was found in the clonal trials that some trees which did exceedingly well in their first year of bearing did not bear another pod for two years. Consequently an experiment was laid down on a two-acre plot of Amelonado seedling cacao, planted in 1949, to find out whether trees which yielded highly in their early years did so at the expense of growth—especially of the roots—and subsequent bearing. There are two treatments in addition to the control; one consists of removing all flowers and flower buds until January 1957, and in the other this will be continued for a year longer. In 1955-56, their first year of bearing, ninety-nine pods were harvested from the 348 control trees. Girth measurements are taken regularly but no differences due to treatments have yet been noticed. The shade in this experiment was greatly reduced during the year and growth has been very promising.

In the eighth P.T.A., girth and height measurements show no reduction in the growth of trees which yielded heavily in their third year in the field compared with those which did not yield.

CUSHION AND FLOWER FORMATION

An experiment has been commenced, in conjunction with

Mr Wharton, to examine the initiation of cushions from leaf axils and to find out how regularly they bear flowers. Two-year-old seedlings were selected, on which all leaf axils were labelled and weekly counts of flowers made. No results are yet available.

COCOA PREPARATION AND QUALITY

CHEMICAL INVESTIGATIONS (T. A. Rohan)

Introduction

Because of the small size of some farms in the Gold Coast, cocoa is fermented in small quantities, sometimes in as little as 15–20 lb. lots. It is also common knowledge that the farmer often reduces the fermentation time below the recommended six days in an attempt to cut down weight loss. Such methods, it is generally considered, may result in a lower quality cocoa than would be obtained under more carefully controlled conditions. In order to determine how far the methods which may be used by farmers do, in fact, influence the standard of West African Amelonado cocoa, a comprehensive series of experiments was designed, in which physical measurements were made and changes in chemical constitution investigated during different types of fermentation. As a preliminary, investigations were made into the chemical constitution of the raw material used.

Catechins and anthocyanins in West African Amelonado

By chromatography on a column of powdered cellulose (Solka Floc.) using the solvent layer of amyl alcohol—acetic acid—water (4 : 1 : 5 v/v) and examining the effluent by paper chromatography, four catechins were identified by their R_F values in the three solvent systems, butanol—acetic acid—water (4 : 1 : 5), amyl alcohol—acetic acid—water (4 : 1 : 5), and phenol—water (1 : 1).

TABLE 26

Cocoa catechins

<i>Catechin</i>			<i>Butanol-acetic</i>	<i>Amyl-acetic</i>	<i>Phenol</i>
			R_F	R_F	R_F
No. 1	..	..	0.66	0.42	0.50
No. 2	..	..	0.74	0.52	0.39
No. 3	..	..	0.58	0.28	0.27
No. 4	..	..	0.48	0.23	—

Comparison of the figures in Table 26 with established R_F values for catechins shows that No. 1 corresponds with (-)-epicatechin, No. 2 with catechin, No. 3 with gallocatechin and No. 4 with epigallocatechin.

The two principal anthocyanins also have been isolated on a column of Solka Floc., and it has been shown by acid hydrolysis that they are both derived from cyanidin, which was identified by colour reactions (Robinson & Robinson, *Biochem. J.*, **25**, p. 1687, 1931) and its R_F value (0.69) when chromatographed in butanol—2N hydrochloric acid (Bate-Smith, *Biochem. Soc. Symposia*, **3**, p. 62, 1949). A study of the partition coefficients between dilute mineral acid and amyl alcohol, before and after salt addition (Robinson, *Biochem. J.*, **26**, p. 1647, 1932), has resulted in the identification of the more mobile pigment as a monoglycoside and the slower moving one as a pentose-glycoside. By acid hydrolysis of each pigment and paper chromatography of the hydrolysate it has been shown that the glycosidic residue in both is glucose.

MacLean (33rd Quarterly Report, p. 13, 1954) reported that 'the purple pigment in fresh, unfermented beans appears to consist of a purple residue in addition to the two anthocyanins indicated'. Forsyth (*Nature, Lond.*, **164**, p. 25, 1949) had already shown that in addition to the main pigments there occurred a cyanidin diglycoside, but that this was only a minor constituent. Exhaustive extraction of fresh unfermented Amelonado cocoa with dilute hydrochloric acid gave a completely colourless residue. Chromatography of the extracts on paper with butanol—acetic acid showed only the presence of the two main pigments with a small amount of coloured immobile material which remained on the starting line—probably Forsyth's diglycoside. It would appear, therefore, that there are no coloured pigments other than those already reported, and that although one acid treatment results in incomplete extraction of the anthocyanins, all are probably taken up in proportion to their relative solubilities and to the extent of their occurrence in the bean.

The colourless residue, on boiling with 20 per cent. hydrochloric acid, gave cyanidin. Hydrolysis with 0.5N sulphuric acid (Forsyth, *Biochem. J.*, **51**, p. 511, 1952) gave a solution of sugars as indicated by a positive benzidine reaction. Paper chromatography with butanol—acetic acid gave two spots R_F 0.27 and 0.33, on spraying with ammoniacal silver nitrate. These could not be separated from glucose and arabinose respectively, but separated readily from galactose, xylose and rhamnose. The insoluble residue after complete extraction of the coloured pigments might therefore contain a leucoanthocyanidin arabino-glucoside, which gives cyanidin and the two sugars on hydrolysis.

Quantitative chromatographic analysis of the polyphenols

Two-dimensional paper chromatography of an acid extract of ripe Amelonado beans, first with water and then with the solvent layer of butanol—acetic acid—water (4 : 1 : 5), gave a chromatogram in which all the main anthocyanins, leucoanthocyanins and catechins appeared as discrete spots on applying a spray containing equal volumes of ferric chloride and potassium ferricyanide solutions. The distribution of the polyphenols on this chromatogram was similar to that found by Forsyth in the case of I.C.S.1 cocoa, and it was again evident that the use of water as a developing agent separated the anthocyanins, catechins and leucoanthocyanins into clearly defined composite groups in ascending order of mobility.

For quantitative analysis 0.5 ml. of an extract of ripe Amelonado beans (10 g. beans in 50 ml. 0.1N hydrochloric acid) was applied to a sheet of Whatman No. 1 paper as a streak 22 cm. in length, and developed with water until the solvent front had travelled 30 cm. After drying, the chromatogram was cut into strips 1 cm. wide and each strip, in 1 per cent. sulphuric acid (10 ml.), titrated against 0.01N potassium permanganate.

A graph of ml. permanganate against number of strips, measured from the origin, gave distinct peaks for the four main classes of polyphenols—anthocyanins, catechins, and the two leucoanthocyanin groups.

The application of Forsyth's technique (*Biochem. J.*, **60**, p. 108, 1955) to West African Amelonado confirmed the suitability of this method for a study of the changes in the polyphenols which take place during fermentation, drying and storage.

Fermentation

A series of experiments has been carried out in which small quantities of cocoa have been fermented under varying conditions. Batch size was varied between 20 and 250 lb. of wet beans; duration of fermentation was four, five or six days; frequency of turning included treatment on the second and fourth days, the third day only and no turning. Each experiment has been conducted with the beans in baskets and in heaps.

Fermentation temperatures have been recorded from mercury-in-glass thermometers placed at the top, centre and bottom of the fermenting masses. Changes in moisture content of the beans and in pH of the pulp and cotyledons have been recorded for each experiment, and quantitative estimations of the polyphenols have been made at regular intervals. Percentage weight losses during fermentation have been calculated and percentage recovery of dry beans

recorded. Appearance of the beans at the end of each fermentation has also been noted.

The results of this work are now being assessed and will be published later.

Effect of storage on purple-bean content

Fermented and dried cocoa has been deposited at warehouses of Messrs Cadbury & Fry throughout the Colony and Ashanti. Humidity and temperature are being recorded in the warehouses, and moisture determinations and purple-bean counts made every two months on bean samples.

A SURVEY OF FARMERS' FERMENTATION METHODS (R. J. Benstead)

Samples and questionnaires have been received from only 214 of the 300 selected farms. The samples have been graded and the data await the appointment of a statistician, although it is possible that the poor response has invalidated the investigation.

INSECTICIDE AND FUNGICIDE STUDIES

POLLINATION STUDIES (Helen M. Entwistle)

The aims of this recently re-opened study are to obtain information as to the identity and biology of insects pollinating cacao, about which little is known, and later to estimate what effect, if any, routine spraying for capsid control has on pollination. The experiments in progress are described below.

Entomological observations

The identities and relative densities of pollinating insects are being investigated by means of routine collections in two plots, one on the Square Mile and the other on the Old Station. Samples of approximately a hundred cacao flowers are taken during different periods of the day, and any insects found in them kept and identified. So far (January-March), the commonest insects collected have been Cecidomyiids, which were most numerous in February and March, when they were found in 12-15 per cent. of flowers. An attempt to determine whether Cecidomyiids are effective pollinators is being made by caging them on flowers covered before opening. The three species of Ceratopogonid (*Forcipomyia ingrami* Carter, *F. ashantii* Ingram & Macfie, and *Lasiohelea litor aurea* Ingram & Macfie) discovered by Billes (*Trop. Agric., Trin.*, **18**, p. 151, 1941) and Posnette (*J. hort. Sci.*, **25**, p. 155, 1950) are very rare, occurring in less than 0.1 per cent. of

flowers. Both Cecidomyiids and Ceratopogonids occur throughout the daylight hours, but are commonest during the middle of the day.

In order to assess the relative densities of pollinating insects throughout the year, by the method described above, estimates of the relative numbers of flowers available for pollination are being made. The amount of pollination actually taking place is being assessed by routine collections of flowers which have been open for twenty-four hours; these are examined in the laboratory to see if pollination has occurred. A check on this method is provided by counting the numbers of sets on similar trees.

A search is being carried out to discover the breeding sites of the pollinating insects. Ceratopogonid larvae live in decaying vegetable matter, and several genera have been bred out of fallen trunks in the cacao. They are now awaiting identification.

Botanical observations

To estimate the efficiency of pollinating insects it is necessary to know whether pollen deposited at the base of the stigma is effective in causing fertilization. This is being investigated by hand-pollinations, and the preliminary results obtained indicate that the stigma is receptive along its whole length, and not just at the divided apex. Experiments to determine how long unpollinated flowers remain on the tree and for how long the stigma remains receptive to pollen have been laid down.

IBADAN SUB-STATION VIRUS RESEARCH

(R. M. Lister and J. M. Thresh)

THE HOST RANGE OF CACAO VIRUSES

A visit was paid to the British Cameroons to investigate the reported occurrence of *Cola chlamydantha* in the Southern Bakundu and other forest reserves near the cacao-growing regions. This species was not found and it appears to have been confused with *C. lepidota* K. Schum., *C. pachycarpa* K. Schum. and *C. rostrata* K. Schum., all of which also have digitate leaves and occur as understorey trees in the lowland rain forest around Kumba. No symptoms suggesting virus infection were found on any of the specimens collected, and in the limited number of tests which were made with mealybugs, no virus was transmitted from the *Cola* spp. to cacao.

The distribution of baobab trees in the cacao-growing areas of the Western Region has been investigated with the help of the Cocoa Survey Division of the Department of Agriculture. They occur in many of the villages around Ibadan, Ife, Akure and Abeokuta, and

are common in the transitional zone between the lowland rain forest and the derived savannah, which occurs along the northern margin of the cacao areas. Some transmission tests have been carried out, but virus has not been detected in any of the trees tested. It is intended to increase the scope of this work and particular attention will be paid to the baobabs in the area around Alaparun, where cacao trees have been found infected with a virus resembling isolates transmitted from baobabs in the Gold Coast by workers at Tafo.

NIGERIAN ISOLATES OF CACAO VIRUSES

The collection of isolates has been enlarged by the addition of material from several new outbreaks which were discovered during the year. The range of symptom expression is not so great as that in the collection of virus isolates made in the Gold Coast. This may be a true difference, possibly connected with the greater extent of the cacao-growing areas in the Gold Coast, but it may be also due to the fact that collection of infected material was started relatively recently in Nigeria.

Detailed symptom recording has been started on a number of selected isolates. Some of these produce only stem swellings, others only leaf symptoms of various types, while most produce both. It is intended to carry out some protection tests to investigate strain relationships.

The virus from Asalu was originally reported in 1948 (*Ann. Rep. WACRI*, 1947-48, p. 11). It has characteristic leaf symptoms and is the only cacao virus adequately tested that has never been experimentally transmitted with mealybugs. Recently, several new outbreaks of a similar type have been reported around Asalu and at Shagamu. Although the virus has not yet been transmitted by mealybugs, the distribution of infected trees suggests that there is a vector. The outbreaks have not been cut out and are being observed for further spread.

EFFECT OF NIGERIAN ISOLATES ON GROWTH AND YIELD

Several experiments have been completed on the effects of various isolates on the growth of seedlings infected at the bean stage. The results extend our preliminary observation, recorded in *Ann. Rep. WACRI*, 1954-55 (p. 94), that the isolates differ in the severity of their effects on seedlings. Some significantly reduce leaf area and number, besides causing a reduction in total fresh and dry weights. In general, the differences between isolates have been consistent from experiment to experiment, but a few have had a greater effect on growth in some trials than in others. This may be because some of the isolates are in fact complexes, mild strains of them having been used

in some experiments but not in others (compare Posnette & Todd, *Ann. appl. Biol.*, **43**, p. 433, 1955).

Since August 1954 monthly records have been taken of individual tree yields for the 827 trees of farmers' cacao at Koroboto, which were taken over by the Cocoa Survey Division as an Observation Plot. The plot is in the Area of Mass Infection and unrestricted spread of virus has been mapped by monthly symptom observations, started in September 1953. Records are therefore available of the length of time each infected tree has shown symptoms, although the date on which each became infected is unknown.

Crop data for the first year (August 1954–July 1955), which are summarised in Table 27, have been analysed for the effect of infection on yield. The average number of undamaged pods produced by trees which showed symptoms at least one year before the beginning of yield recording was about half that for trees which had not shown symptoms by October 1955 (the difference being significant at $P=.01$). There was evidence that the yield of trees which first showed symptoms in the year ending September 1954 was also less than that of the symptomless trees.

TABLE 27

Effect of a Nigerian Cacao virus on yield of undamaged pods

Koroboto Plot, 1954–55

<i>Symptoms recorded</i>		<i>Trees</i>	<i>Pods per tree</i>		<i>Wt. of pods (lb.)</i>		<i>Wt. wet beans (lb.)</i>	
			<i>Mean</i>	<i>S.E.</i>	<i>Mean</i>	<i>S.E.</i>	<i>Mean</i>	<i>S.E.</i>
Before Sept. 1953 ..		49	8.8**	1.7	7.4**	1.5	2.19**	0.42
Sept. 1953–								
Sept. 1954 ..		52	11.0*	2.0	9.4*	1.7	2.71*	0.46
Sept. 1954–								
Oct. 1955 ..		69	16.6	2.6	13.4	1.9	3.86	0.54
Symptomless† ..		98	16.1	1.9	13.2	1.5	3.76	0.43

† A random sample of the 657 symptomless trees, omitting 'contacts'.

* Significantly different from symptomless trees at $P=.05-.10$.

** Significantly different from symptomless trees at $P=.01$.

Figures for the weight of pods and of wet beans showed a similar trend, but there was no evidence that virus infection reduced the average weight of individual pods or their bean content. The yield differences would probably have been increased if black-pod control had been practised, because Thorold (*J. Ecol.*, **40**, p. 125, 1952) has shown that in Nigeria the incidence of this disease on a particular tree tends to vary in proportion to the number of fruits set.

This evidence from Koroboto and comparable figures from a similar plot at Offa Igbo suggest, therefore, that the types of cacao

virus occurring in these areas reduce yields by an amount depending upon the length of time the trees have been infected. This conclusion is equivocal, however, because it depends on the assumption, which may or may not be justified, that the samples of infected trees are exactly comparable with those of healthy ones, apart from the primary and possible secondary effects of virus infection. It has been noted at Koroboto and Offa Igbo that infected trees tend to be more severely affected by capsids, thrips and general deterioration of the canopy than the adjacent symptomless cacao. This may be a secondary effect of virus infection, or due to the chance association of virus with the other factors. Additional work is planned to elucidate this point. It is intended to compare the yield of healthy and infected trees on areas which are sprayed, to eliminate the complications caused by capsids and thrips.

MOVEMENT OF VIRUS IN CACAO SEEDLINGS

The movement of virus was followed in double-stemmed cacao plants, produced by removing the growing point a short time after germination. The two stems and their respective roots were separated at various times after infective mealybugs had been fed on one of the growing points. The growth made by the stem on which no mealybugs had fed remained healthy if the separation was done within twenty-four hours of the start of the test-feeding period. Measurements showed that the virus must have moved at least 10 cm. away from the point of inoculation within the twenty-four-hour period. This rate of movement is comparable with that recorded, in plants whose rate of translocation is low, for viruses which it is thought must be injected directly into the phloem (Bawden, *Plant Viruses and Virus Diseases*, p. 295, 1950).

HEAT TREATMENT OF VIRUS-INFECTED PLANTS

A number of cacao seedlings infected with different virus isolates were grown at a controlled temperature of 38°C. for periods up to four weeks. Leaves with symptoms were produced while the plants were in the high-temperature chamber and after removal to the glasshouse, so the treatment did not eliminate the viruses and apparently had little effect on their symptom expression.

COPPICING AS AN ADJUNCT TO CUTTING-OUT FOR CACAO-VIRUS CONTROL

Work with the Cocoa Survey Division has been continued on the control of outbreaks by cutting out all obviously infected and some apparently healthy trees, and coppicing the surrounding cacao to a distance of thirty yards from the nearest symptom-bearing tree.

Between March 1954 and December 1955 attempts were made to control forty-seven outbreaks in this way. Detailed records and plans are being kept of the distribution of additional infected trees revealed by coppicing, in relation to that of the ones cut out. During the initial treatment 4,862 infected and 6,913 apparently healthy trees were removed and 45,879 apparently healthy ones coppiced. Growth from the coppiced stumps has been satisfactory on most of the plots; although capsid and goat damage have been reported, and many trees on certain plots are showing severe symptoms of iron deficiency.

The most striking feature of the results is the very small number of infections diagnosed by coppicing apparently healthy trees. Others will no doubt be revealed by further inspection, but so far only 0.07 per cent. of the coppiced stumps have been found with chupons bearing symptoms. There is great variation in the results obtained, even when outbreaks of a similar size are compared; but, as would be expected, there is a tendency for most of the infections revealed by coppicing to be in the larger outbreak areas. Where the inspection parties have recorded the distribution of infected stumps, they have usually been found to occur in the first or second ring of 'contacts' surrounding the area which was grubbed out. These preliminary results extend our earlier conclusion that relatively few apparently healthy trees in the vicinity of an outbreak are in fact infected, particularly when it is a small one. It therefore seems likely that the present 30-yd. limit could be reduced with little loss in efficiency and considerable saving in time and expense. Against this it might be argued that treatments during the period 1954-55 were not drastic enough, because infected standing trees have been found in the immediate neighbourhood of nine of the coppiced plots. The distance between the originally treated outbreak and these additional infections is extremely variable. In the treated plot at Sokun a 'new' infection was found in the first row of standing trees on the edge of the coppiced area, and slight extension of the original treatment would have included it. On other plots, 'new' infections were found at up to 100 yards or more from the originally treated outbreak, and for initial treatment to have included these trees would have involved immense wastage.

The simplest explanation of the occurrence of outlying infections around a large central outbreak is that they are 'satellite outbreaks', arising through 'jump-spread' from it. There is, however, no method of determining at present when such an explanation is correct. Each large or small group of infected trees could have become independently infected by spread from a more distant common source or from several distinct sources. Even where outlying infections are

related to a main outbreak, it does not seem that they can be expected with a frequency greater than one in four of the outbreaks treated. Moreover, it seems unlikely that it will be possible in the immediate future to predict the occurrence, extent and position of outlying infections at the time the main outbreak is treated.

It was anticipated that chupons from infected stumps would all give symptoms within a few months of coppicing. This has not proved to be so—the inspection parties have been finding infected stumps at the third or fourth re-inspection, which may be more than a year after initial treatment. The chupons on these stumps may have become infected after coppicing, but this is considered unlikely because the ‘new’ infections usually appeared near the sites of original outbreaks. Moreover, the effect has been observed at the special WACRI observation plot at Ogo, where chupons on ten of the coppiced trees which were known to be infected have so far failed to give symptoms, although frequently inspected during the eight months following coppicing. Factors influencing delay in symptom production are being further investigated. It may be due to the poor growth of chupons which have developed the ‘paint-brush’ condition (see p. 87), or to severe mineral deficiencies making it impossible for leaf symptoms to develop. Alternatively, the effect may indicate that virus is not present in the stumps and root systems of certain trees at the time of coppicing, or that this treatment enables mild strains to become dominant in the new growth (Posnette & Todd, *loc. cit.*).

It has been agreed with the Department of Agriculture (Western Region) that the 30-yard limit to the treatment of apparently symptomless cacao round outbreaks in the Area of Intensive Survey should be retained throughout 1956, but that during this period only visibly infected trees should be cut out and the remainder coppiced. In this way, additional information should become available from which to evolve the most efficient and economical control methods.

ANCILLARY OBSERVATIONS ON COPPICED CACAO

Sixteen acres of an old spacing trial at the Ibadan Native Administration Cacao Station (I.N.A.) have now been coppiced in the schedule of experiments started in May 1954. The results to date were presented to the Symposium held at Moor Plantation on 17–18th February 1956, and as it is intended to write up the work in detail for publication, only a brief summary is given here.

When cacao trees are coppiced the stumps rapidly develop chupons from the base. These have always been found to arise from cushions or from the axils of leaves (the homologous morphological position

on trees which are not bearing). The numbers of cushions and chupons have been found to be proportional to coppicing height, but experiments in which trees have been cut at 3, 6, 9 or 12 in. from ground-level have shown that, in determining whether a tree will regenerate or not, the effect of coppicing height is relatively unimportant compared with that of canopy condition (see Table 28, p. 89). There was a suggestion from the results that the probability of regenerating badly damaged trees is increased by coppicing higher, and our provisional recommendation is that trees which are in a reasonable condition should be coppiced with a sloping cut from 6 to 3 in., whereas badly damaged ones should be cut from 9 to 6 in. Wherever possible a low coppicing height should be employed, as this facilitates earthing-up and the development of roots on the chupons. There is also less likelihood of wind and termite damage to the regenerating chupons if they develop from stumps coppiced near ground level.

The growth of chupons from coppiced stumps has been found to be related to tree girth at the time of coppicing. Height and girth measurements on the chupons and observations on jorquette formation and appearance of flowers have all shown that growth is directly proportional to the girth of the parent stump. The average girth of chupons on the largest stumps after eighteen months' growth is almost double that of those on the smallest, while flowers and cherelles are almost entirely confined to chupons on stumps with a girth greater than 12 in.

Experiments are in progress in which one, two, three or four chupons are allowed to grow from coppiced stumps at various spacings. Growth measurements eighteen months after coppicing show that the size of the largest chupon on each stump is unaffected by the presence of additional ones, but if a second chupon is allowed to grow on the stump it makes only about 90 per cent. of the growth of the largest one. The third and fourth chupons make 80 and 70 per cent. respectively of the growth of the largest, and there is a corresponding delay in the time taken for them to produce jorquette branches and flowers. The chupons in these experiments are just beginning to bear pods, and it is intended to obtain information on which to base recommendations as to the optimum number of chupons to leave on a coppiced stump for the highest yield per acre.

Most of the common insect pests of cacao have been noted on the chupons at I.N.A., particularly on the observation plot which has received no routine insecticidal treatment. Little difficulty has been experienced in controlling capsids, despite the fact that infestations have been severe on immediately adjacent standing trees. In the early stages the chupons were painted at monthly intervals with

0.5 per cent DDT emulsion, and more recently they have been spray-painted (*Ann. Rep. WACRI*, 1953-54, p. 16) with the preparation at 1 per cent. Larvae of the Noctuid moth *Earias biplaga* Wlk. have been the most serious insect pests on the chupons, causing death of the growing point. Adult beetles of the genus *Tragocephala* have caused similar though less widespread damage, largely confined to the rainy-season months.

In the experiment to investigate seasonal effects on regeneration, samples of fifty or more trees were coppiced each fortnight from December 1954 to November 1955. It was noted that the appearance of chupons was accompanied by flower production on the stumps of trees coppiced between December and early April; but few flowers appeared when coppicing was done after the first week of April, and none when it was done after the first week of June. A further effect of season was on the incidence of what has come to be known as 'paint-brush', a term used to describe abnormal chupons. These have shortened internodes and shed their leaves prematurely, either in the bud or soon after development, so that they may be quite leafless; although the stipules often persist in a terminal cluster, giving a 'paint-brush' appearance. The disorder was not found on new growth developing from stumps coppiced during December and January, but amongst later coppicings its incidence increased progressively to a maximum after treatment in June, when chupons on 48 per cent. of the stumps were affected. The development of chupons with 'paint-brush' was thus associated with the onset of the rainy season; but there was no clear correlation with rainfall after coppicing, because most of them developed normally from the stumps of trees coppiced after early August, despite the fact that the rains continued until November.

Although some deaths were noted, most of the chupons which showed 'paint-brush' in the weeks immediately after coppicing did eventually recover, by the development of axillary buds of normal appearance. Recovery was evident about three months after coppicing and the chupons are now making good growth after the initial check. We have, as yet, no explanation to offer for the disorder or its markedly seasonal appearance; although the characteristic symptom pattern is similar to that of leafless-twigg disease in the British Cameroons, and bears certain resemblances to the symptoms of phosphorus and boron deficiency in cacao, as described by Maskell, Evans & Murray (*Rep. Cacao Res.*, 1945-51, *Trin.*, p. 53, 1953).

MEALYBUG STUDIES

(R. G. Donald)

NATURAL ENEMIES OF MEALYBUGS

The survey of natural enemies of mealybugs attacking cacao in Nigeria was terminated at the beginning of the year. Many specimens of Coccinellidae, Encyrtidae, and other natural enemies of Coccidae have since been sent to taxonomists in the United Kingdom. A number of these represented species of which more material had been requested; others were of species in the WACRI collection not previously named, or determined only to genus by comparison with other specimens available in Nigeria. Reports have been received on twenty-five species not previously examined by the taxonomists. These include a number which are probably new and undescribed, of which *Pseudaphycus* sp. near *orientalis* Ferrière is of particular interest, because it appears to be the same as the third species of *Pseudaphycus* introduced into the Gold Coast from America in 1953. The first specimens were collected at Ibadan in November 1955, but as the species is not yet known to have established itself in the Gold Coast its occurrence in Nigeria is unlikely to be in any way connected with the introductions into the former territory.

MEALYBUG POPULATIONS AND DISTRIBUTION

In *Ann. Rep. WACRI*, 1954-55 (p. 102) a brief summary was given of information obtained on mealybug populations while surveying their natural enemies. Additional data confirm that *Planococcus citri* is by far the most abundant species in samples taken from the trunk and lower branches of cacao in Nigeria, but such samples do not give an accurate estimate of the relative abundance of the various species on whole trees. *Pseudococcus njalensis*, in particular, is commoner in the upper canopy than it is at lower levels. Experts consulted about statistical analysis of the figures obtained have suggested that, owing to the very large proportion of colonies of *P. citri* which contain only one individual, this will not be possible without considerably more data.

CAPSID STUDIES

REGENERATION OF DAMAGED TREES BY COPPICING (J. M. Thresh)

Before suitable spraying machines were available for the control of capsids on mature cacao, coppicing was suggested (*Ann. Rep. WACRI*, 1946-47, p. 35) as a method of regenerating trees which had been severely damaged by these insects and the associated complex of fungi (see also *Ibid.*, 1954-55, p. 58; 38th Quarterly Report, p. 9).

The method has been further investigated in Nigeria by experiments at the I.N.A. farm and at Owena in Ondo Province. The condition of all the trees was recorded at the time of coppicing, using the scoring system described in *Ann. Rep. WACRI*, 1954-55 (p. 99), slightly modified to include a class (5) for trees alive at the base only, which have previously been placed in Class 4. Observations showed that the condition of trees at the time of coppicing had an important effect on the ability of their stumps to produce chupons; but there was no evidence that growth of chupons that did develop was at all affected by previous damage to the trees. The results from several of the I.N.A. experiments are summarised in Table 28. It will be seen that there were few failures on coppicing trees which were in a reasonable condition at the time; whereas losses were greater on coppicing trees with their canopy completely destroyed, and approached 50 per cent. for those alive at the base only.

TABLE 28
*Regeneration in relation to canopy condition on coppicing**

<i>Canopy category</i>	<i>Number of trees coppiced</i>	<i>Number of stumps with chupons†</i>	<i>Percentage success</i>
1	50	50	100
2	287	275	96
3	779	743	95
4	745	651	87
5	261	151	58
Total	2,122	1,870	88

* Combined data for five one-acre plots coppiced at various times during 1955.

† Trees scored six months after coppicing.

These results show clearly that coppicing is likely to be successful only if trees have not been allowed to deteriorate to the stage where the fan canopy is completely destroyed, so that they consist of just a main stem, living perhaps at the base only. Furthermore, the trees are only just beginning to bear pods, two years after coppicing, and it is possible that mist-blowing the standing trees with insecticide would have been a more efficient and rapid method of bringing them back into bearing. A further experiment has therefore been started at Owena, with the Entomologist of the Federal Department of Agricultural Research, to compare the two methods of dealing with severely damaged trees.

CHEMICAL CONTROL OF CACAO CAPSIDS (R. G. Donald)

An experiment on the use of BHC against capsids attacking mature cacao in Nigeria has been designed, and will be undertaken during the coming year, with the help of the Department of Agriculture, Western Region. The relative merits of high- or low-volume

spraying and of dusting will be investigated. Treatments at various time intervals from four to twelve weeks and at levels of application from 1 to 4 oz. gamma BHC per acre will be compared. Evaluation of treatments will be by capsid counts, by assessments of canopy condition, capsid damage and regeneration, and by yield records. Sixty-six plots are being selected for the experiment: twenty-two in the Akure-Ondo area have already been approved, while others in the Ilesha-Ife area and in the south of Ibadan Province await inspection.

This experiment is in many ways similar to those undertaken in the Gold Coast by Messrs Plant Protection, Ltd., in conjunction with the Gold Coast Department of Agriculture. One reason why experiments in Nigeria are considered necessary is because treatment of large blocks of cacao by Government is envisaged in the Gold Coast, whereas in Nigeria control will be carried out by individual farmers, many with too small an acreage to justify the purchase of power-driven equipment. Furthermore, the increased yield of Nigerian cacao under capsid-free conditions must be separately assessed. It may not necessarily be as large as that in the Gold Coast because cacao in Nigeria is mainly unshaded and has to contend with a longer and more severe dry season. These factors may limit the returns obtainable from control of capsids.

MINOR INSECT PESTS OF CACAO

(R. G. Donald)

Earias biplaga Wlk. has attacked terminal buds of many of the chupons arising from coppiced stumps at the I.N.A. farm, causing abnormal growth through development of axillary buds and delay in the formation of a true jorquette. At Araromi similar damage was also caused by *Tragocephala gorilla* Thoms., the adults of which 'ring-bark' the shoots several inches from the apical bud before laying their eggs. The larvae bore in the stems, and are capable of killing chupons or seedlings. To date, neither insect has been common enough to be considered a major pest; though with possible increasing use of coppicing, as an adjunct to cutting out visibly infected trees for the control of cacao viruses, attacks by these and other insects on chupons may increase. Observations are therefore being made on their occurrence and distribution. Damage due to *T. gorilla* has so far been less widespread than that caused by *E. biplaga*, being largely confined to the rainy-season months.

A collection of other minor pests of cacao has been started at the Sub-station.

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